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VARIATION IN SOME JAMAICAN SPECIES OF PLEURODONTE.

BY AMOS P. BROWN.

C. B. Adams, in his *Contributions to Conchology*, No. 11, published in 1852, gives some "Hints on the Geographical Distribution of Animals," in which he points out that "each species occupies one geographical area only; but, inasmuch as natural types are of all grades of value, the difficulty of discriminating species is great. The difference between some types which inhabit distinct areas is slight and in some cases perhaps impossible to demonstrate; nevertheless, they should be regarded as distinct species. Still it may occur that exceptions to this rule exist, and frequently a number of pairs of such analogues from distinct areas may be so arranged that the amount of difference between each two shall successively diminish from species that are very distinct to species that are scarcely distinguishable, and at last the series shall terminate in two forms quite indistinguishable from each other; that is, in one species. These areas of species vary from a few miles to several thousand miles. Areas of insular terrestrial species, excepting those with the power of flight, do not usually exceed the islands they inhabit, and where the islands are separated by 100 miles or more of water examples of species common to two or more are rare."

In a previous article, published in the *Contributions*, No. 10, 1851, "On the Nature and Origin of the Species of Terrestrial Mollusca of the Island of Jamaica," he says: "Among the *terrestrial shells*, typical forms exist in great profusion. These forms are of every conceivable grade of value, from varieties up to genera and families. They have also a determinable geographical distribution. . . . The island in this respect is a miniature continent." In considering the nature of the species, Adams remarks: "Our first conclusion is this: that in many groups the species are distinguishable by *types* only and not by well-defined limits. This may be illustrated by a figure, in which species are represented by circles, many of which are in contact and whose areas are sprinkled irregularly with dots which represent the varieties. One central dot represents the type of the species. . . . On the boundaries of the species we find varieties which closely resemble their neighbors in the adjacent species, while their affinities with the central types of both species are so nearly balanced that it is not really a matter of much consequence on which side of them the imaginary boundary line of the species is drawn. . . . It should be observed that the boundaries of the circles do not represent any facts which have an objective existence. With the boundary lines we represent the species as described in books; without them we see the species as they exist in nature."

"Since the sub-types of species are distributed with great regard to locality, it is obvious that much perplexity which results from the graduation of species into each other is avoided by those travellers who take but a few specimens from distant localities and by those collectors who are satisfied with a single, well-characterized specimen of each species. Such collections are valuable as exhibiting types, but they very imperfectly represent the *relations of types*." When we consider that Adams wrote these articles almost a decade before the publication of the *Origin of Species,* we must be struck by the modern view of a species which he takes. It was forced on him by the great variability exhibited in the land snails of Jamaica, which he was studying. In the foregoing paragraphs he lays down the general principles of their variation as he saw it and points out the necessity of collecting large series of specimens if we would become acquainted with the relations of the forms to each other. Thus he says that each species occupies one geographical area, and, as he found in this island, these areas may be small. If we only compare selected types from isolated areas the differentiation of the species is easy; but when we disregard the artificial limits we set for one species and examine not selected specimens, but large series, "*we see the species as they exist in nature*." They vary from station to station, from one set of conditions to another. Tracing the same species from one place to another or finding it living under different environments, the variations represented by the dots on his hypothetical diagram grade one into another and, as he points out, we see that "our circles (which include the species) *do not represent any facts which have an objective existence;*" in other words, our species are purely subjective. The case is perhaps not quite as bad as might be judged from the above, for the examination of a large series of specimens from a single locality may show all grades of variation between the central type and the surrounding forms; or, on the other hand, it may show a remarkable uniformity in the entire series, with only variations in the dimensions. Thus, in one *subspecies* considered in this paper, forms from a single locality could be selected, which, if reported from different zoological provinces, or even neighboring islands, would be given distinctive specific names by any systematist, and yet may have come from a single hill slope where the animals were free to migrate from one part to another. But, on the other hand, in another species which we might examine from the same locality we would find great uniformity in a large series of specimens.

Adams also calls attention to the fact that an insular fauna resembles a continental fauna in little, "the island is a miniature continent." "Among the terrestrial shells typical forms exist in great profusion; these forms are of every conceivable grade of value, from varieties up to genera. They also have a determinable geographical distribution." This makes the island of Jamaica an excellent field for the study of variation and its controlling factors. A complete zoological survey of even such a contracted area as is covered in this paper, (better still if extended to a wider area or to the entire island), would be of the greatest value in the study of the causes of variation, so far as they may be worked out by morphology. The possibilities in this direction appealed very strongly to me during a visit to the island in February–March, 1910, and on a subsequent visit in April–May I collected large series of specimens from definite colonies with this end in view. From a study of the large series of species of *Pleurodonte* taken at this time some facts in regard to the causes of the variation observed seem to be indicated, and they will be found embodied in this paper. In my first visit in February–March I was assisted in the collecting by Mr. Stewardson Brown, who was studying the flora of the region. At this time I had not recognized the importance of collecting by isolated colonies, and the series of specimens we obtained, while useful for biometric measurements on the species of the region as a whole, do not give the data necessary for tracing out the progressive variation from point to point. In my second visit I collected by colonies, keeping each one separate, and thus obtained material for a comparative study. This material has been gone over and individual measurements of each shell made; these measurements have been plotted in various ways and the results compared. The variation in measurement gives a quantitative method of comparison which eliminates very largely the personal equation, and therefore it has been resorted to first in all of these comparisons. The two dimensions of altitude and diameter, plotted as a point, give the best comparison of the dimensions, their ratio to each other, or the index, may likewise be used; and the indices arranged in order and plotted for each colony on one diagram show the variations in the slope of the shell or give a key to the mean divergence. The dimensions, reduced to an average for each colony, may also be compared, and when these are arranged in order geographically, on one diagram, they give a view of the successive variations from station to station.

I included in the specimens taken a considerable number of the old "dead" or semi-fossil shells which are to be found in the soil and in the "graveyards," as they may be called, the great accumulations of old shells that are found at the bases of cliffs, in crevices and in the little "cockpits." More of these should have been taken, for I found on studying them in connection with the living forms of the same colony that additional light was thrown upon these living forms. But their importance was not fully recognized in the field, as each day's collection was simply packed away for later study. They often show much variation from the living forms, and, while many of these "semi-fossil" specimens probably represent the form of the species before the settling and clearing of the country, they also show the amount of variation which may have taken place in a given locality. While it is probably impossible to fix the time that has elapsed since these forms were living, this was probably not great; yet they give an indication of how rapidly organisms may vary when living under conditions that favor variation. Their study, too, may throw some light upon similar variations that are noted in palæontological studies, and some of them may actually be fossils.

In order that the conditions at each colony may be comprehended, a description of this part of Manchester Parish and of the individual colonies will be necessary (see map, fig. 1).

Mandeville is located about the center of the parish of Manchester, some 14 miles in an air line from the sea at Alligator Pond on the south of the island of Jamaica and 35 miles in an air line from the north coast. It is south of the "backbone," or main east and west elevation of the island, which lies some 12 or 14 miles to the north. It is on an elevated plateau which extends to the northwest of Mandeville, to Balaclava, Accompony, Ipswich and the "Cockpit Country." The surface is very uneven, but the individual hills are not large nor high; the small valleys are not very deep. Westward from Mandeville are seen several parallel lines of hills, running north-northwest and south-southeast, and becoming higher to the westward until at about 6 or 8 miles to the west the ground slopes abruptly down to the Black River Valley and the level savannas of St. Elizabeth Parish, which are but little above sea level—a drop of 2,000 feet. To the east and northeast the ground slopes down to the valleys in which Williamsfield and Porus are located, at an elevation of some 1,000 feet lower than that of Mandeville. The country has been settled for many years; in some places but little original forest remains, in others, especially to the north, northwest, west and southwest of the town, large tracts are still covered by original forest. The underlying rock is the Tertiary limestone which forms the surface of Jamaica outside of the great uplift of the Blue Mountain system and belongs mostly to the Cobre formation of Hill. These limestones are generally nearly horizontal or only gently inclined, they outcrop on steep slopes of the hills and many hill-tops and stand up in long cliffs on the hillsides. There is no surface water in the district, but the limestones are eaten out into caverns and the drainage is underground. Some of the limestone layers are very pure, some are quite marly. The weathering of the rock depends upon these characters and the two types of stone mentioned present quite different structures when they weather. The marly limestone shows but little in the way of corals or shells or other fossils, being rather even in grain and evidently

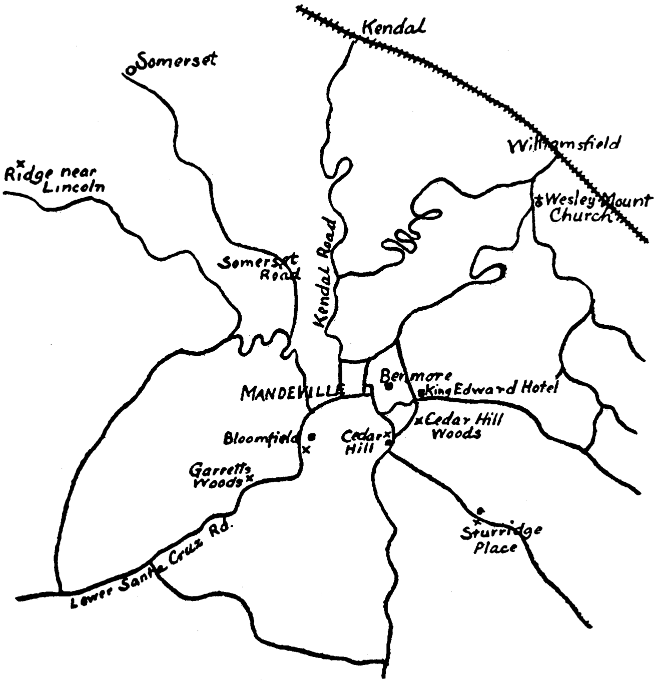

Fig. 1.—Sketch map of the Mandeville region.

containing considerable clay. The pure limestone layers are composed of a compact, fine-grained form of calcium carbonate which encloses numerous corals and marine shells; but these, being of the same composition as the ground mass, weather equally with it, and hence do not come out entire by the solution of the stone, but only appear on the surface in section.

The layers of marly limestone upon weathering break up into blocks of varying size, and tops of hills formed of these layers are covered with loose, detached blocks of all sizes. An examination of any of these boulders shows at once that they are very porous and loosely held together; when they disintegrate, the rock passes into a coarse gravel, composed of small angular fragments, and finally into smaller fragments and clay. The residual clay from the marly rock is white to buff-colored, or sometimes yellow-ochre color. This rock, on hill-tops, weathers deeply, by boulder weathering; its porous character makes the soil drain quickly after rain, and such hill-tops are notably dry. They are generally flat-topped, if the hill is of considerable size, and are covered with a growth of the "broom-palm," the leaves and debris from which cover the ground to the depth of several inches. This coating of dead leaves on the ground is generally so dry that the snails find little to feed on in it, and these dry hill-tops furnish few specimens of land gasteropods.

The purer limestone layers, on the other hand, do not weather into blocks by boulder weathering, but the rock passes at once into a fine clay, which is generally very dark red to reddish-brown, as Hill describes that of the Cobre formation. This residual clay, of course, does not persist on the exposed surfaces of rock on the hill-tops, but is washed off by the rains into the hollows and valleys. This pure limestone presents bare rock surfaces that are not porous, and do not absorb moisture; they are not smooth, however, but are honeycombed with irregular holes and cavities, some of large size, and these are, in miniature, the structures characteristic of the Cockpit country. Thus vertical or inclined cylindrical holes or pits may be seen in this limestone, ranging from two or three inches to ten feet in diameter, and often as many feet in depth. The surface of the rock is rough and jagged, sharp spires and knife-edges are characteristic of this pure limestone on the hill-tops. The rock is not porous, but the holes and pits retain the moisture; and the limestone is such a good conductor that moisture condenses and remains on the surface after the deposition of dew each night. These limestones are the most favorable places for land snails. In the country about Mandeville the marly limestone often forms the hill-top, and the purer limestone is found at a lower level; and this is true along the hills to the northwest also, towards Somerset and Green Vale, but the crest of the still higher hill, fronting the plain of St. Elizabeth, is mainly composed of the pure limestone. The marly rock, weathering more slowly, would form the hill-tops in the more or less uneven plateau in which Mandeville is located, but along the escarpment edge of this plateau to the west the purer limestone can form the ridge. While there are certainly several different alternating layers of these two types of rock, the general observation holds true that wherever in the island the purer, honeycombed, jagged limestone is encountered, the land molluscs are more plentiful and larger.

When Jamaica was untouched by cultivation, there is little doubt that all the upland limestone district, and in fact all the surface, except the swamps and savannas, was covered with a continuous forest. Cliffs of rock and exposures of bare rock on some hills were the only exceptions. Under such conditions free migration of the land molluscs from one part of the island to another was possible. In the Mandeville region, where there is no surface water, but the topography is characterized by cup-shaped valleys enclosed by hills, often with no possible connection for surface flow of water from one valley to another, the entire surface was forested before the introduction of cultivation, some 50 years ago. In many places virgin forest is still to be seen on hill-tops, and sometimes extending down into valleys and gullies and connecting hill with hill. The land that is first cleared is in the small cup-shaped valleys, where the soil and humus washed from the wooded hills collect; as the area of cultivation extends, it involves the slopes of the hills and the cultivated or cleared areas join, but they have islands of virgin forest, in the form of the rocky hill-tops, which are not only not arable, but the clearing of which would be a positive detriment to the estates. This is fortunate, for in these islands the plants and animals find a refuge from the encroaching "cultivations." Many of these woods have existed in their present state since the first clearing of the land, and are only occasionally entered now for the cutting of a little firewood or an occasional hardwood tree for lumber, and there is every reason to believe that they will continue to exist unchanged for generations. Each one of these isolated patches of woodland becomes a definite colony for the land molluscs, many of which colonies have existed in their present state for periods varying from 20 to 70 or 80 years. In these areas are found not only the present living snails, but the shells of their ancestors, accumulated in "graveyards," such as the small cockpits, rifts and holes in the cliffs, and in the rock piles and soil. The dead shells are also found in the soil of the cultivated and cleared land, and may readily be obtained for comparison with the living forms now confined to the isolated patches of virgin forest or islands. The district is hence one well adapted to the study of the variation which has taken place since the advent of cultivation in the country.

In a paper[1] published in these PROCEEDINGS by Pilsbry and Brown a list of the species collected in this Mandeville district is given and the exact localities at which I collected the species is recorded. Most of these localities represent definite colonies, and all that are treated of in this paper are isolated colonies. In order that the environment under which the animals lived may be compared, descriptions of these localities will be necessary. Of these Benmore woods, the King Edward Hotel woods, Cedar Hill woods and Bloomfield are in the limits of Mandeville Market; Garrett's woods, Somerset Road 3 miles north of Mandeville, Kendal Road, Ridge near Lincoln, and Somerset are at some distance from the town.[2]

THE BENMORE WOODS COLONY.

This woods covers a hill to the east of the Court House at Mandeville and about a quarter mile distant. It is practically virgin forest on the west slope of the hill where collections were made and includes an area of 6 or 8 acres, the woods extending down to the bottom of the hill on this side. The elevation ranges from 2,000 feet above sea level to perhaps 2,150 feet. The limestone outcrops on the slope and is the pure rock weathering into honeycombed and irregular forms. Where collections were made the ground was moist, covered with a thick coating of leaves and often of loose stones. The leaves furnished abundant fungus food for the Pleurodonts. The shade was dense and this helped to preserve the moist condition. Live *Pleurodonte* were plentiful, some had invaded the neighboring pasture, but were mostly recorded by the dead shells found lying about. Collection was not extended to the hill-top, which was partly cleared and much dryer. It was probably composed of the more impure limestone seen on the top of the neighboring hill at King Edward Hotel.

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[1] The Mollusca of Mandeville, Jamaica, and its Environs, by Henry A. Pilsbry and Amos P. Brown, *Proc. Acad. Nat. Sci. Phila.*, 1910, pp. 510–535.

[2] See map, fig. 1, reproduced from the above paper.

THE KING EDWARD HOTEL WOODS COLONY.

This piece of woodland also occupies a hill-top, situated across the road from the King Edward Hotel, and lying to the east of the Benmore woods about half a mile distant. It is a conical hill of some 3 or 4 acres, densely wooded, but the wood more open and rather dryer than that at Benmore. Not much limestone is seen in place until near the top of the hill, where low exposures as well as numerous loose blocks are encountered. The limestone is the more impure kind, weathering into blocks of all sizes and producing a great quantity of loose stone in small pieces. The hill is not very high and the elevation is about 2,000 feet above sea level. Roadside cuttings have been made along the west side of the woods, where a certain amount of talus from the hill makes an accumulation of loose small stones that are good collecting places. Where the woods is not stony, a layer of leaves of some inches thick covers the slopes of the hills, and in this many living Pleurodonts were found. Along the road to the west many were obtained crawling in the gutters after rains. The woods is isolated by roads on two sides and open pastures on the other sides as well as across the roads. It is practically virgin forest.

THE CEDAR HILL WOODS COLONY.

This rather small woods occupies the northwest slope of a hill on the estate called Cedar Hill or Cedar Grove, and extends from a road at the foot of the hill to the top, where it is bounded by open pasture land, as it is on the southwest side, while cultivated ground bounds it to the northeast. Across the road is open pasture land, extending to Benmore woods, and about a quarter mile to the northeast is the woods at King Edward Hotel. This is a very dense jungly woods, exceedingly rocky; the pure limestone cropping out on the entire hillside, and extending to the hill-top, which is covered by loose blocks of limestone. It is evidently an undisturbed piece of the virgin forest, as can be seen by the flora as well as by the species of mollusca obtained here. The limestone being well exposed and, as usual, much honeycombed by holes, the collecting was good. "Dead" shells were especially plentiful.

THE BLOOMFIELD COLONY.

The Bloomfield estate lies to the southwest of Mandeville Court House, and the collections were made along a roadside cut and cliff for perhaps a quarter mile on the Lower Santa Cruz Road, including, too, the strip of woods at the top of the cliff. This is much disturbed, but has evidently been recently a piece of original forest. The limestone is in general rather marly; the road runs up hill here from about 2,000 to 2,100 feet above sea level along this cut. "Dead" shells are plentiful, many species were only found in this state. From the list found here it is seen that at one time the fauna must have been much like that at the Cedar Hill woods. *Pleurodonte acuta goniasmos* was evidently well established, as great numbers of young snails of this species were seen crawling actively about. While still a productive locality for many species, there is no great amount of original woods remaining.

Garrett's Woods Colony.

This is the woods on a hill adjoining Mr. Garrett's place, "The Bungalow," and is a piece of virgin forest about 2 miles from Mandeville Court House on the Lower Santa Cruz Road. It occupies the top and part of the slope of a rocky hill (2,200 feet above sea level) with numerous limestone exposures and loose blocks, the hill being capped by the marly limestone, mostly in loose blocks here and underlaid by the purer limestone. The wood is rather dense and moist, the coating of dead leaves on the ground furnishes abundant fungus food for snails. The top has the moist character of the slopes and shows no broom-palm. The limestone on the slopes is partly honeycombed with cavities, and some species, such as *Zaphysema macmurryi* (C. B. Ad.) and *Pleurodonte* (*Eurycratera*) *jamaicensis* (Gmel.), which are rarely seen except in favorable localities in virgin forest, are found here plentifully. *Annularia fimbriatula* (Sowb.) is also very abundant; it is rarely seen except in undisturbed woods. Mr. Garrett informs me that the woods is practically in an undisturbed condition, and is rarely entered except to cut a little firewood. The moist rocks and the honeycombed character of the stone, with the abundance of food, makes this a very favorable habitat for several of the species collected. The woods is completely isolated by open fields and pastures from neighboring patches of woodland and will probably remain in its present condition for many years to come. It has been isolated now for a generation or more, but has remained practically untouched for that time. It was one of the few places where *Stoastoma pisum* (Sow.) was seen alive and moving actively about, up to the top of the hill. The Zaphysemas and Pleurodontes were taken principally from the slopes and near the top.

Ridge Near Lincoln Colony.

To the west of Mandeville the ground rises in a series of ridges, broken by gaps and with a general north-northwest to south-southeast trend. The crest of the main ridge is reached by taking a branch of the upper Santa Cruz Road, which leaves the post road about 3 miles to the west of Mandeville Court House and runs among the hills to Lincoln. At about 6 miles west of Mandeville and somewhat short of the hamlet of Lincoln the main ridge is crossed in a gap occupied by this parochial road, and from this point the ridge was followed some half-mile to the north-northwest. Near the road the larger trees have been cut, but following along the rocky hill-crest one soon passes into untouched virgin forest. From the top of this crest the Santa Cruz Mountains may be seen some 10 miles away across the Valley of Black River. The ridge is formed of the purer limestone, honeycombed by holes and small cockpits, and standing up in sharp spires. The hill is covered with a dense growth of jungle. The elevation of the highest point reached was about 2,800 feet above sea level. *Zaphysema macmurryi, Pleurodonte jamaicensis, P. acuta goniasmos* and species of *Sagda* were very plentiful. Their dead shells were seen, in rifts in the cliffs and in the cockpits, by the peck. The smaller holes in the limestone were frequently several feet deep, the cockpits were often ten feet and more deep. Careful search was made for living *Zaphysema macmurryi* and *P. jamaicensis,* but while dead shells of both species could have been gathered by the bushel (and many of these were in perfectly fresh condition), no living specimens were encountered. They probably live deep in the holes of the limestone and in the cockpits, and would hardly be seen alive on the surface unless during the rains, which at the time I collected here, May 3, had hardly begun. The conditions of moisture and the character of the vegetation resembled those of the Garrett's woods locality, but in this case the ridge is continuously wooded for some miles with scarcely a break and the forest extends down the slopes for a considerable distance, so that there must be several thousand acres of woodland along this ridge that is more or less continuous. The breaks that occur in the continuity of the forest could probably be crossed by migrating snails during the rainy season, though, at the time of my visit, the dry slope at the end of the hill towards the road would have offered an impassable barrier. To the north, however, it must be nearly continuous forest to Balaclava and the uncultivated Cockpit Country. To the northeast lies the Somerset colony, in a similar forested area, but the intervening valleys are many of them cleared and cultivated. The part examined could be strictly called one colony, but, doubtless, on following out the ridge to the north, many more or less isolated colonies would be encountered.

SOMERSET ROAD COLONY.

This is a small colony 2½ miles from Mandeville at the turn in the parochial road to Somerset, between the 2 and 3 mile posts. It consists of small roadside exposures of limestone in little quarries and borrow pits along the base of a rocky wooded hill. The limestone is principally the marly variety, and while not weathered to the porous character which this stone acquires on hill-tops, the soil is nevertheless rather dry. The woods are not very dense, but the ground is covered by a layer of some inches of leaves which furnish enough food to support a good population of *P. acuta goniasmos* and many smaller snails, as *Colobostylus jayanus rufilabris*. The collection here was made in about 100 yards of the wood, mostly near the road. The entire patch of woodland was perhaps a couple of acres, but it was only partly isolated from much larger tracts of forest in the adjoining hills to the west. The elevation was somewhat below that of Mandeville, probably 1,900 feet above sea level. In all directions except to the southwest this point of hill is isolated from the lower ground by open pastures. It is about half-way between Mandeville and the Somerset estate, some 3 miles from each, and nearly as far from the Kendal Road colony. Larger forms, such as *P. acuta goniasmos*, could undoubtedly travel during the wet season into this locality from the neighboring wooded hills to the west, southwest and south, but the forms living to the north and east would be completely isolated by cleared land.

KENDAL ROAD COLONY.

In collecting out this road 3½ miles from Mandeville, but few large stretches of untouched woodland were found that were favorable for collecting and that reached the post road. The hills were generally wooded; sometimes the forest was practically virgin, but pastures or cultivations isolated them from the road. After passing down the steep zigzag part of the road, in the lower ground, a few pieces of favorable woodland were met with, and along the roadside exposures at one of these places some specimens of *Pleurodonte* were taken. They must have lived in the few acres of woodland, for here the cultivation is more intensive, and this colony would have been completely isolated by open country from any others. It was very noticeable here, an old cultivated district, that the old weathered shells were very different in form from those that were in new, fresh condition. The wood was not entered, so no living forms were taken. The fresh shells collected were from those that had crawled down into the road during rains and been destroyed by ants, the older ones were from shell accumulations in the fissures in the rocks.

THE SOMERSET COLONY.

This large estate of some 3,000 acres was visited in February, 1910, and in May I spent a week here as the guest of Mr. A. P. Sutherland collecting molluscs. The property lies on either side of the parochial road (known as the Somerset road) which leads to Medina and Balaclava, and the estate is entered at a point about five miles from Mandeville. From here it extends along the road for a couple of miles. The house at Somerset was built more than half a century ago, but the property is still in virgin forest with the exception of such pastures and cultivations among the hills as have gradually been cleared during the last 30 or 40 years. The surface is very irregular, with a network of narrow valleys and sinks more or less connected, between the meshes of which the round or oblong hills stand up boldly. The topography has been mainly produced by the solution of the limestones forming caves, which have fallen in, making the deep sinks, bowl-shaped valleys and deep gullies that form the network of depressions. The limestone stands up in bold escarpments and cliffs fronting the depressions, and these cliffs follow along the general trend of the hills; in many cases they seem to represent the faces of fault blocks. The main system of these cliffs runs nearly north and south—north-northwest by south-southeast, as a rule; the hills follow these lines in a large number of cases. A more or less continuous depression is followed by the road through the estate, but this is not continuous, and the road is therefore very hilly. Less than half a mile to the west of the road over the first range of hills is a similar and more continuous depression or valley, with a more continuous range of hills rising abruptly on the west, and so the steep hills continue to rise in succession until at about 2½ or 3 miles to the west of the Somerset barbecues and house the ridge overlooking the valley of St. Elizabeth is reached—a continuation of the "Ridge near Lincoln." All of the depressions (except some deep gullies and sinks) and some of the less stony slopes near the parochial road are cleared and partly under cultivation, but this cleared area represents less than one-fourth of the surface near the road, and in the valleys further from the road even less has been cleared. Many of the old cultivations have been abandoned for years and the jungle or "bush" very rapidly covers such abandoned, cleared land. Most of the land at present cleared is in pasture, although some small plantings of ground vegetables, coffee, bananas, etc., have been made. The hills are so close to each other, only separated, as a rule, by pastures, which are often planted with oranges and pimento, that migration of snails from one to the other would be possible during wet periods. That such migration frequently takes place does not seem very likely, but the possibility of it makes the entire tract practically one colony. Even on the same hill it is easy to find evidence that much migration of the forms is not common, but that it occurs in some cases there is good evidence.

Collections were made in the gullies, sink holes and dissected caves that represent the virgin conditions in the low ground; also in the pastures where many forms live, and in the wooded hills, which are everywhere covered by the original forest. More than 20 such hills were explored with thin intervening valleys, an area of several hundred acres. The lower ground and many of the hill slopes are underlaid by the purer limestone, many of the cliffs on the hillsides consist of it, as do the sides of the dissected caves and the sinks (cockpits), and some of the tops of the lower hills. The higher hills are capped by the marly limestone, which covers them with loose blocks of the weathered porous stone, for the rocks are rarely in place here unless the cliffs extend up to the hill-top, which they sometimes do. As a rule, the hills are somewhat flat-topped. On such hill-tops the rocky surface is largely covered by a vigorous growth of the tall, slender palmetto, known as the "broom-palm," above which the hardwood trees of many kinds extend their dense shade. While well-shaded, these hill-tops are, nevertheless, dry on account of the porous nature of the limestone and the deep coating of leaves of the palmetto, which latter decays very slowly and is very porous without forming much humus.

In contrast to this dry condition is the very damp character of the sink holes and deeper gullies in the limestone which are so shaded that even the tree ferns flourish there all the year round. Some of the smaller hills, notably one to the west of the road near the southern edge of the estate are composed of the pure limestone which becomes honeycombed by the action of the weather, and is so liable to develop small sinks and cockpits. In this little hill just mentioned the vertical circular holes abound, many up to 10 feet in diameter. It was in one of these little cockpits that the best specimens of the large extinct form of *P. acuta goniasmos* were procured. Specimens as large as these were not found in the living state, but many from the gullies and lower ground approximated to their dimensions and shape. From a study of the distribution of this species and observations on other species, it is evident that the size is largely a question of moisture, good cover and abundant food, on the one hand, and dry conditions, with poor food supply and generally poor cover, on the other. Favorable conditions as to shade and even as to the character of vegetation (as absence of palms, etc.) may yet produce small forms where there is a deficiency of moisture. Such a case is the sink hole back of the barbecues on the Somerset place, where the forms were rather small because the rock was not honeycombed with holes, and hence the cover was not very good. The conditions of moisture were not the most favorable on account of the overhanging walls, but still the sink was not especially dry. But food was not plentiful and cover was rather lacking. Even the *P. a. goniasmos* was small, as was the *P. jamaicensis* also; but the very fact that this species was found at all, shows that the conditions were rather favorable. Observation on a great many localities on this estate shows that, as regards the distribution of the various sizes of any one species, this is dependent on the character of their habitats, which may be roughly classified as follows:

A. Deep gullies and cavernous or honeycombed rocks, giving good cover, abundant food and moisture, produce large well-fed forms. This region is confined to the uncleared valleys and gullies and the bases of the hills here, but may extend to hill-tops also, as at the small hill noted on this estate and the higher hill at the Ridge near Lincoln.

B. Slopes of hills rising from the more level ground, disturbed woods and isolated hills wooded to the top not covered by the palmetto, yet in virgin forest or bush where the conditions as to shade are favorable, but the rock cover not so good as in A and the food supply not so plentiful, produce the average medium-sized forms in great numbers.

C. Hill-tops, especially those covered by the palmetto called "broom-palm," where the rock cover is wanting and food is not plentiful and where the conditions are dry except after rains, have few and small forms.

In the condition C there is generally another unfavorable feature present, namely, the nests of the large black ant, which in such places builds nests of 7 or 8 feet high and 3 feet in diameter on the ground or in trees. In many cases these nests or ant cities are very old and have exercised an influence for years. Near such ants' nests no shells were seen dead or alive, although sometimes dead shells were encountered within 50 to 100 feet of such nests. The white termites (called locally "duck-ants") also build large dome-shaped nests, but more often on the slopes, and I did not see that they had much influence on the distribution of the molluscs.

Pleurodonte (Eurycratera) jamaicensis Gmel. Plate VII.

Good series of this species were obtained from Somerset, Ridge near Lincoln and Garrett's woods, and a few specimens from Benmore woods, Bloomfield, Cedar Hill woods, and the woods at King Edward Hotel. While these vary considerably in size, the same general form is preserved, so that from the smallest to the largest specimens the dimensions show a nearly even gradation. On account of the shape of the shell, comparable measurements could only be obtained with any approach to accuracy by making certain conventions in regard to the position in which the height and width should be measured. The "height" is measured from the apex of the shell to the outer edge of the lip, the greatest obtainable measurement being taken; the width is measured from just above the upper angle of the lip to the opposite whorl, the measurement being taken whorl to whorl. The height so obtained is not far different from that measured parallel to the axis, but is, of course, much more exact. The height of the mouth was also measured from the same angle of the lip to the tangent-point on the portion of the lip opposite and was found to range near the diameter of the shell. This species is still living at the first four localities mentioned, but, from the appearance of the shells collected, it is most likely extinct at the Bloomfield, Cedar Hill and King Edward Hotel woods. The specimens from Garrett's woods ran uniformly smaller than those from the other locations; of 28 adult shells but 3 exceed 38 x 49 mm. and but one shell of this species from all other localities is as small as this, and that one is an injured shell from the Benmore woods which was stunted by the injury. Of the 28 shells from Garrett's woods mentioned, 18, or 64 per cent., ranged between 35 x 45 mm. and 37 x 47 mm.; but one fell below 35 x 45 mm. and only three were above 38 x 49 mm. The largest shell from this locality was 39 x 52 mm. The index or ratio of width to height ranges from .735 to .82, with 75 per cent. of the shells between .77 and .79. Of the other large series, the Ridge near Lincoln colony and the Somerset group are nearly of the same size, ranging from 40 x 51 mm. to 45 x 57 mm., with the exception of one small specimen from Somerset which was evidently abnormally small, due to some irregularity in growth, as was indicated by the growth lines.

The Somerset colonies furnished shells of more uniform index or ratio of width to height than those of the Ridge near Lincoln colony; this index ranges from .76 to .815, but of the 30 specimens measured from the Somerset locality only 3 fall below .77 and only 6 are above .80. Of the other 21 (or 70 per cent.) which range from .77 to .80, inclusive, 18 (or 60 per cent. of the whole series from Somerset measured) have an index between .78 and .80. From the Ridge near Lincoln colony the range in the index is from .78 to .83; of the 16 examined 4 (or 25 per cent.) were below .79, 6 (or 37½ per cent.) ran between .79 and .80, and a like number were above .80, and of these, 4 (25 per cent.) were above .82.

The few scattering specimens collected at the other localities mentioned are all larger than the majority of the Garrett's woods suite, but the index is very variable, ranging in the Benmore suite from .73 to .80 in six examples.

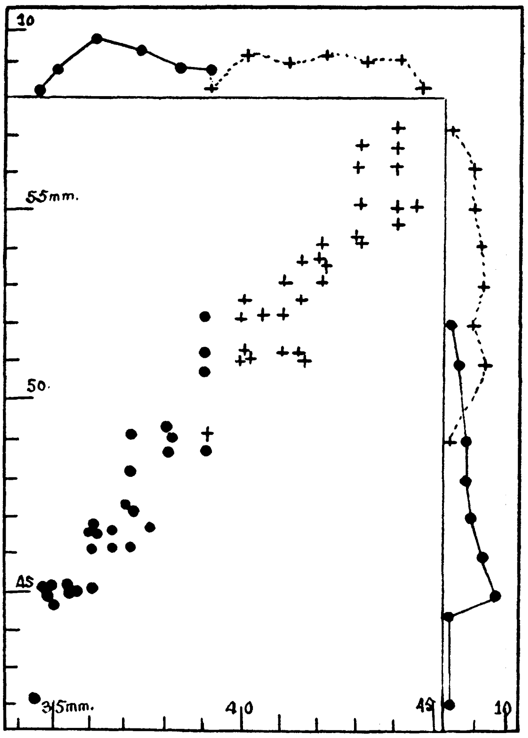

Fig. 2.—*P. jamaicensis.* Garrett's Woods and Somerset Colonies.

A comparison of the forms from the Garrett's woods colony with those of the Somerset and Ridge near Lincoln colonies may be made by examining figs. 1 and 2, which are plotted from the measurements of height and width. From these figures the relative variations can be readily seen. Averaging all the measurements gives about the following:

	Height.	Width.	Index.
Garrett's woods colony, average of 28	46	36	.78
Somerset colonies, average of 30	53	42	.795
Ridge near Lincoln colony, average of 16	54	42	.775

Fig. 2 shows the comparison of the forms from the Garrett's woods colony and the Somerset colony; the former represented by the black dots, the latter by the crosses. As will be seen, there is a gradation in size from one to the other, but the two groups do not mingle; the index is about the same in the two colonies. The size of the shell is given by the millimeter scales, the vertical scale on the left giving the height, while the horizontal scale below gives the width. The frequency curves for width are plotted at the top and those for height on the right. It will be noticed that there is no overlapping in the widths, which run from 34½ to 39 mm. for the forms from Garrett's woods and from 39 to 44½ mm. in the Somerset forms. But in the heights there is a certain amount of overlapping, as the frequency curves show.

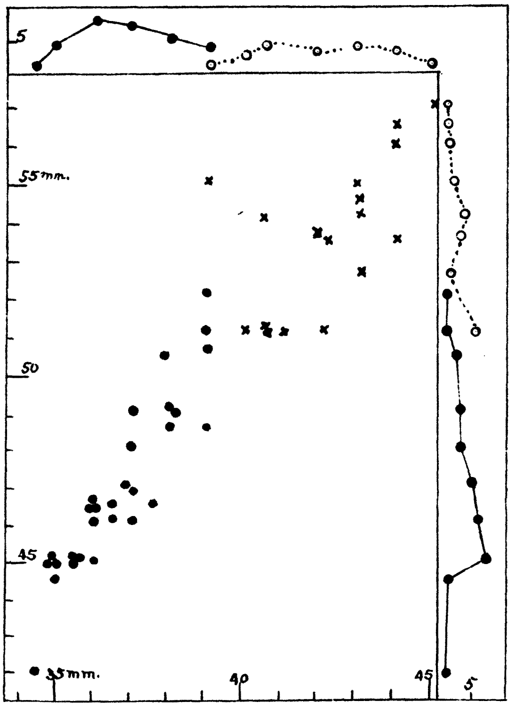

Fig. 3.—*P. jamaicensis.* Garrett's Woods and Ridge near Lincoln Colonies.

In fig. 3 a similar comparison of the Garrett's woods forms with those from the Ridge near Lincoln is given. Here again there is no mingling of the two groups and the frequency curves for width do not overlap, but those for height do so slightly. In plotting all the frequency curves the half-millimeter measurements were distributed to the nearest whole millimeter.

The variation here shown indicates that the Ridge near Lincoln and Somerset colonies are much alike, and indeed these two localities are connected by nearly continuous woods, but the smaller forms from Garrett's woods have been living here for years since their isolation by the clearing of the woods and have become a smaller race in this time. The forms from nearer Mandeville were larger than those from the isolated Garrett's woods colony.

Pleurodonte bainbridgei Pfr. Plate VIII.

Of the large series of this species in the collection of the Academy of Natural Sciences there are two specimens from Mt. Diabolo, St. Ann Parish, which are stated by Jarvis to be typical of the species. They are evidently the extremes of the series found at this locality. One is very near the *P. bainbridgei pretiosa* C. B. Ad. The other is the ordinary type of this species and is similar to those forms found in the immediate vicinity of Mandeville. They are stated to be extinct at Mt. Diabolo and are described as "semi-fossil." That they are really extinct, however, would require an examination for young of the species at the locality, as living adults of this species were not seen during the time of my visit at any of the localities in the Mandeville region considered below, while young shells in very fresh condition were found where the adult empty shells taken were all as weatherworn as either of these two Mt. Diabolo specimens. The two Mt. Diabolo specimens differ in many particulars, but as they came from the sides of the road that crosses the hill they very likely are from different colonies. As Mt. Diabolo is on the water shed dividing the island into north and south portions, it is quite possible that these two types represent a northern-side and a southern-side race. This is rendered still more probable by the variations in the Mandeville district specimens studied, which seem to indicate two races that, in some parts, have intermingled.

The *P. b. pretiosa* type from Mt. Diabolo measures 30 mm. in height by 55.5 mm. in width, with an index of .54, which is considerably lower than many shells of this type that I collected in the Mandeville district. The shell consists of 5⅓ whorls; on the last half of the last whorl the suture is strongly impressed and the periphery is slightly elevated into an angle that is easily felt, forming a slight keel. The impressed suture is produced by a lowering of the suture line in this part of the last whorl and a wounding of the whorl. This depression of the suture is only to the periphery of the preceding whorl, however, and not below it, as in the typical forms of *P. b. pretiosa.* In this specimen the umbilicus is only half covered by an expansion of the lip. The other specimen is somewhat larger, measuring 32 mm. in width by 60 mm. in height; the index is .534—nearly the same as the last. The shell consists of 5¼ whorls (therefore slightly less than the last), with the suture on the last half of the last whorl only slightly impressed; the periphery in this portion of the shell is flattened, not keeled, and is even slightly impressed. The umbilicus is completely closed by an expansion of the lip.

Compared whorl by whorl with the specimens that are considered below, either of these runs somewhat larger after the second whorl, up to which point there is little difference in any of these forms.

Pleurodonte bainbridgei Pfr. Plate VIII, figs. 1, 2.

At Somerset colony.

Shell moderately elevated with about 5½ whorls, which are more compressed and rounded in the last 1½ whorls than in the Ridge near Lincoln colony, and in fact are the form that has been described as *P. b. pretiosa* by C. B. Adams. The suture at the end of the last whorl drops below the periphery by 1 or 2 mm. in many cases; and in two that were abnormally developed due to an injury; the dropping of the suture line amounts to 3 or 4 mm. and extends around the shell for the last half whorl. A number of the shells from this colony were very old, "subfossil," and yet they did not differ appreciably from the fresh living shells, showing that this form has not been interfered with by the clearing, or at least not altered in form by it. These semi-fossil forms were carefully measured, but they give substantially the measurements of the living adult forms of this locality. The average size is: width 53.2 mm., height 33.2 mm., index .62 x 5. The size varies considerably, however, from 48 x 32 mm. to 54 x 34 mm.; the index ranges from .588 to .694. The mean divergence varies from 110° to 115°.

Pleurodonte bainbridgei Pfr. Plate VIII, figs. 3, 4.

At the Ridge near Lincoln colony.

Shell with only moderately depressed spire, consisting of slightly over 5¼ whorls, the suture of the last half of the last whorl but slightly depressed, much less so than in typical forms of *P. b. pretiosa* C.B.Ad.

The periphery on the last whorl is not angled nor keeled, but is evenly rounded. The range of size in the 18 specimens examined varies but slightly, and the form is nearly the same in all (it is a rather homogeneous colony) and the average dimensions are: height 30 mm., width 54 mm., index .555. Mean divergence about 120°. While the young shell is strongly keeled, this sharp angle of the periphery of the shell is completely lost at 4½ whorls, so that no angle appears along the periphery on the last whorl. The umbilicus is normally closed by an expansion of the lip, but in two shells (one of which is damaged) the expansion does not entirely cover the umbilicus.

Pleurodonte bainbridgei Pfr. Plate VIII, figs. 5, 6.

At the Garrett's woods colony.

Shell with a moderately depressed spire, the outline of which is somewhat concave to linear, with 5¼ whorls, of which the last is only slightly depressed along the suture in the last ⅓, or in some cases not at all depressed; the periphery is slightly angled on the last whorl up to within ¼ whorl of the end or in one or two cases up to the end, otherwise rounded in the last ¼ whorl, and resembling the more depressed specimens from the Ridge near Lincoln. Umbilicus completely closed by the expansion of the lip in all of the specimens. The average dimensions are: width 53.3 mm., height 29.6 mm., index .555, mean divergence 125°–135°. Number of specimens, 10.

Pleurodonte bainbridgei Pfr. Plate VIII, figs. 7, 8.

At the Benmore colony.

Shell with depressed spire, consisting of 5 whorls or less, with a suture that is not at all impressed or only impressed on the last ¼ whorl; the periphery of the shell is slightly angled to the end of the last whorl, this being caused by the last whorl's being somewhat flattened on that part just above the periphery and sloping away rather sharply below. The umbilicus is closed by an expansion of the lip. The dimensions are: width 50⅔ mm., height 27⅓ mm., mean divergence about 125°, index 54.

Pleurodonte bainbridgei Pfr. Plate VIII, figs. 9, 10,

At the Cedar Hill colony.

Shell with rather depressed spire, consisting of 4⅞ to 5 whorls; the suture on the last ¼ of the last whorl scarcely at all depressed, and this part of the whorl rounded at the periphery and scarcely angled beyond 4⅓ whorls. The umbilicus is generally completely closed, but in two specimens it is only about ⅔ closed by the expansion of the lip. Average dimensions are: width 52 mm., height 26.7 mm., mean divergence 140°, index .515.

Pleurodonte bainbridgei Pfr.

At the King Edward woods colony.

Shell depressed, consisting of somewhat less than 5 whorls ($4\frac{3}{4}$ to $4\frac{7}{8}$), the last whorl rounded or slightly angled at the periphery and with little or no depression at the suture, except at the end of the last whorl in some cases; umbilicus closed by an expansion of the lip. The single (outer) tooth is very small or nearly obsolete. Average dimensions are: width 50.6, height 26, mean divergence about 140°, index .513.

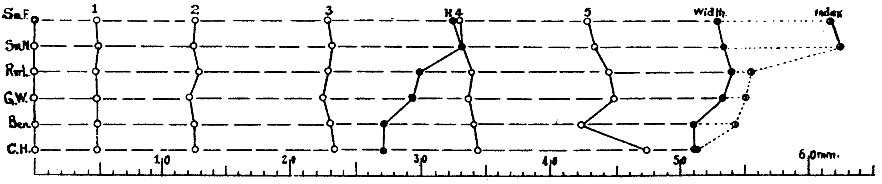

Fig. 4.—*P. bainbridgei.* Comparison by whorls, width and height.

Fig. 4 gives a comparison of the average sizes of this species from five of the stations where collections were made, and from the Somerset estate I have plotted the dimensions of the extinct shells as well as those now living. They are marked Sm. F., the Somerset extinct; Sm. N., the Somerset normal living forms; R. nr. L., the forms from Ridge near Lincoln; G. W., the Garrett's woods colony; Ben., the Benmore woods forms; and C. H., the forms from Cedar Hill. Measurements were taken of each shell, whorl by whorl, with the height and width, and these were then averaged and the index calculated, this being the ratio of the height to the width. These dimensions are plotted, the diameter at whorl 1, whorl 2, etc., being marked 1, 2, 3, 4, 5; and the greatest width is indicated by the black dots marked "width." The height of the adult shell, in the same way, is indicated at H. The indices are marked "Index." It will be noted that the Somerset forms have a high index and, as noted, resemble the forms that have been named *P. b. pretiosa* by Adams. The five localities represented on this figure are arranged geographically from Somerset to Benmore woods and Cedar Hill woods, and it will be noticed that there is a fall in the index from one locality to the other, but a rapid fall from the Somerset station to the Ridge near Lincoln station. This is accompanied by an actual as well as a relative drop in height of the shell, so that the height curve resembles the index curve, but this is natural as the width curve shows less variation. The shells from the Benmore woods colony were not very healthylooking, and this may account for the apparent stunting shown towards the end of their shells after the reproductive organs have developed, as indicated in the curves for "whorl 5" and "width."

Pleurodonte acuta goniasmos A. D. B.

This very variable species is the common large *Pleurodonte* in the Mandeville district. Some 500 specimens of adult shells were collected in this region from the definite colonies above described, as well as about a hundred immature shells; and, in addition, about 150 others from mixed colonies were taken, which are not considered in this comparative study. The largest collection was from the Somerset colonies, a suite of 229 being secured here of the adult shells, as well as a large number of young. Measurements of all of these six hundred shells (adult and immature) from definite colonies were made, and from these curves showing the distribution of dimensions plotted as well as the whole series of dimensions. From the young and from breaking down the whorls of adult and young shells measurements were secured in each case, from which measurements the growth curves of the development of the shells were worked out. Besides these measurements of height and width (the two dimensions recorded for all specimens), in the case of each colony, a small number of typical shells were selected and measured as to the diameter at each whorl, and these were averaged (as well as the heights and widths, and the indices with the mean divergence) and all these factors were plotted to scale. From this last diagram (fig. 6) it is at once seen that the differences in dimensions vary with the geographical position of the colonies and that at least two lines of migration are involved in this region. In the tract examined these begin at Somerset and at the Kendal Road colony, respectively, and, making two series of the colonies arranged in geographical order from these points, two sets of curves are at once obtained in which the graduation in dimensions is regular from one end to the other (fig. 6). The two lines, the Somerset wave and the Kendal Road wave, converge from the northwest and from the northeast towards Mandeville, where they are only separated by about a half-mile; and, doubtless, to the south of Mandeville colonies could be found that show a mingling of these two races. That they were originally one there is no doubt, but they branched off to the north and east from the main common stock and, following the topography of the country and the most favorable ground, became separated, but eventually came together again. In this migration through the "Manchester backwoods," as Chitty calls this region, the animals undoubtedly followed the lines of least resistance, where conditions of food and moisture (the main controlling factors in the case of this species) were most favorable, and they avoided the places where conditions were unfavorable or where resistance to migration was offered by the nature of the ground, such as dry, stony hills, continuous cliffs and very steep slopes. Of course this dispersal and migration was effected ages before the country was settled and cleared. On the basis of these apparent migration lines, the colonies may be divided into two groups. Starting in the area examined with the Somerset colony, we have one group including in order the following localities: Somerset, Somerset Road, Ridge near Lincoln, Garrett's woods and Bloomfield, forming a chain of colonies in one of the migration waves. The other may be taken as starting from Kendal Road 3½ miles north by east of Mandeville and includes the group: Kendal Road, Benmore woods, Cedar Hill woods and King Edward woods, the last three being localities to the east and southeast of Mandeville Court House. From the large number of specimens collected at Somerset the possibility of variation at any one large station could be studied; and as the variation noted in the different colonies depends upon the same factors that control it in the case of the Somerset group of colonies, a study of the species at this station will serve as an introduction to the comparative study of the forms from all the colonies, which will then be taken up in order as given above. The migration lines can then be studied.

Pleurodonte acuta goniasmos A. D. B. Plate VIII.

At Somerset.

From an examination in the field four types of the species may be distinguished at this place, which may be designated as follows:

1. Extinct forms that formerly lived in the deep gullies and honeycombed rocks (localities of type A). Probably the nearest approach to the original stock we have any record of. As they were only found in a much weathered, semi-fossil condition, they are assumed to be extinct and will be called "*Somerset extinct.*" Their nearest descendants are the Somerset gully forms 2.

2. What may be called "*Somerset gully forms,*" the forms now living in localities of type A, as described under the Somerset colonies above.

3. Somerset hill slope forms, living under the conditions described under the Somerset colonies above as type B, the higher hill slopes. These may be called the "*Somerset normal forms.*"

4. "*Somerset hill-top*" forms, living on hills on which the broom-palm or palmetto grows (type C locality).

An examination of the measurements of the entire suite of Somerset specimens shows that the distribution of dimensions follow this grouping. From the plotting of the distribution of height and width the relative numbers of the four types are seen to be as given below in the 229 examples studied. The separation into groups by the width measurements is quite sharp, but, as is explained later, the heights overlap somewhat:

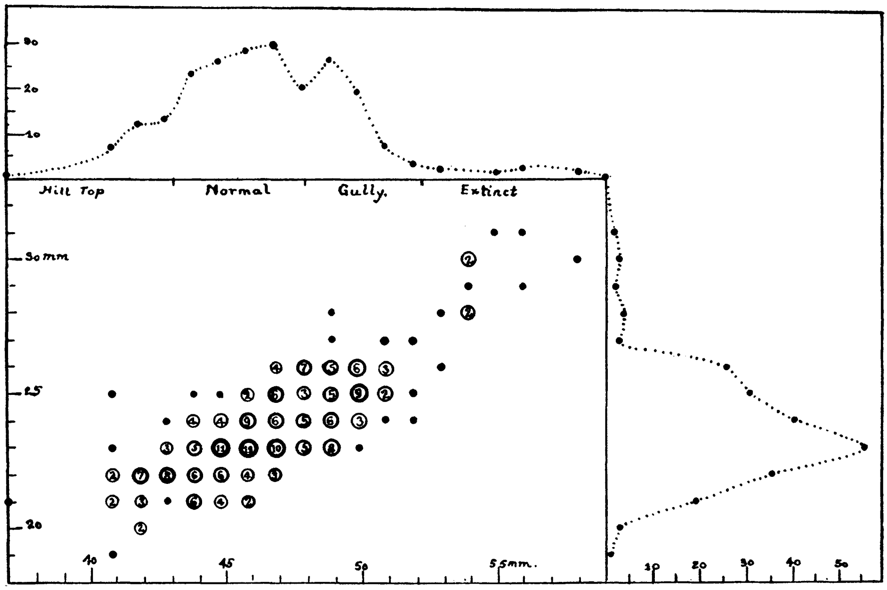

Fig. 5.—Somerset.

Range of Dimensions in the Four Types at Somerset.

Type.	No. of examples.	Range of width, mm.	Range of height, mm.
Somerset Extinct	12	60–54	33–28
Somerset Gully	55	54–49	28–25 (23)
Somerset Normal	127	48–44	(26) 25–21
Somerset Hill-top	33	43–41	22–19.5

The curves were plotted for the entire 229 specimens and no attempt was made to sort them out into groups. But nevertheless the curves show the types quite plainly. Thus the widths for the 33 *hill-top* forms 13 are 42 mm. and 13 are 43 mm.; whereas the next millimeter in diameter, 44 mm., is represented by 23 specimens, 45 mm. by 29 specimens, 46 mm. by 26, 47 mm. by 25, 48 mm. by 24; this range from 44 mm. to 48 mm., inclusive, representing the normal forms. At a diameter of 49 mm. we find 26 forms; at 50 mm., 19 forms; at 51 mm., only 7 forms. There are a few scattering *normal forms* in these 52 *gully forms* and a few of the *gully forms* above 51 mm., up to 54 mm., making the number distinguished as *gully forms* up to 55. The 12 *extinct* specimens collected range from 54 to 60 mm. in width.

The curve of the heights does not serve so well to sort out the four types, for exclusive of the *extinct* type there is not so much range in height among the specimens except those of the *gully* type, which vary in height from 28 mm. to 23 mm., though mostly falling between 27 mm. and 25 mm. The curve shows a rapid rise from 19½ mm., of which only one was recorded through 20 mm., of which only 2 examples were measured to 23 mm. as a maximum where the number recorded was 54. Between the heights of 22 mm. and 25 mm. there are included 108 specimens. As has been stated, a small number of characteristic examples of each of the three living types were selected for measurement by whorls and all of the perfect specimens of the *extinct* type collected were used; these measurements were employed in the descriptions which follow.

1. SOMERSET EXTINCT (Plate VIII, figs. 1, 2).—Shell rather more elevated than in the *Somerset gully forms,* consisting of 5¾ whorls, of which the first two belong to the embryonic shell; with an acute periphery which continues to the end of the last whorl; slightly concave next the periphery below up to the beginning or sometimes the middle of the last whorl, somewhat concave next the periphery above to the end of the last whorl; labrum with one outer tooth on the lower side, and sometimes with a second inner tooth; umbilicus normally closed by expansion of the lip. Average height 31 mm.; width 58 mm.; index .535; mean divergence about 115°.

About 60 per cent. of the shells had one tooth, the remaining 40 per cent. had two more or less well-developed teeth. This is a difference from the other Somerset forms now living, which showed 170 out of 209 with one tooth and ten with no teeth, against 29 with two teeth, of which the second inner tooth was often only a trace.

These *Somerset extinct* were found in several favorable localities, but were only collected from one cockpit on the little hill of honeycombed limestone that has been already mentioned. A few specimens were taken (about a dozen), although hundreds were seen here and elsewhere on the estate. It is assumed that they are extinct, as no fresh shells of this large high type were observed; but a protected gully may be found where they are still alive, and they may be living in the Balaclava district. They closely approach 2, *Somerset gully forms*, which are no doubt their descendants.

2. Somerset Gully Forms (Plate IX, figs. 3, 4).—This is the largest living *P. a. goniasmos* of this region. The shell consists of about 5⅛ whorls, the spire being somewhat lower than in the *Somerset extinct* form. The embryonic shell occupies about 1¾ whorls. In form of shell and concavity next to the periphery, as well as in the keeled character of the latter, this shell resembles the *extinct* form; but in many shells the whorl next the periphery is convex below and even above near the end of the last whorl. This convexity of the whorl next to the periphery above is an accompaniment of diminution in size, and is common to almost all of the smaller forms of this species examined from each of the localities mentioned. As this type passes into the next (3), this character becomes normal in the entire last whorl. The labrum has the outer tooth developed in above 80 per cent. of the specimens, but the inner tooth is only present in some 14 per cent.; and somewhat less than 5 per cent. are destitute of teeth. Average height 23.5 mm.; width 50 mm.; index .47; mean divergence about 130°.

The form varies with the convexity or concavity of the whorl next to the periphery above; the more typical forms—those present in the largest numbers—are convex at this point on a part of the last whorl. An examination of the young shells shows that up to 4 whorls the form of the shell is that of *P. ingens* C. B. Ad. or of *P. acuta patina* (C. B. Ad); between 4 and 4¼ whorls it passes into the form of *P. a. acuta* and then rather rapidly into the typical *P. a. goniasmos* form.

3. Somerset Normal (Plate IX, figs. 5, 6).—These forms resemble the more convex type of the gully form and differ principally in size and in having a somewhat higher index, about .52. They are actually higher than the gully form by one or two millimeters when the width is some three millimeters less. The shell consists of 5¼ whorls, or a trifle more than in the gully, but the diameter of the whorls is less in every case and the fifth whorl has a diameter of 41 mm., as against 45 mm. in the gully form. The smaller shells, as a rule, are typically convex next to the periphery above, but wherever this character is well-marked the form is flatter and the index slightly less than in those with a concavity of the whorl at this point. Such more convex and less keeled forms generally measure about as given above, the more acute forms measure 24 mm. by 48 mm. to 25 mm. by 50 mm., with an index of .50, and thus pass into the gully type. They are then the intermediate stage between the present *gully* form living

under the most favorable conditions and the *hill-top* form living under the most unfavorable conditions. They were generally encountered on the sides and near the top of the slope in the hills capped by the broom-palm or in small, somewhat isolated hills, where in both cases the moisture was somewhat deficient and the food, therefore, not so plentiful as in the gullies. An average size was: height 24.5 mm.; width 47 mm.; index .52; mean divergence 125°.

4. SOMERSET HILL-TOP (Plate IX, figs. 7, 8).—These are the smallest form of this subspecies living at this locality, but they are simply a diminutive form of the *normal*. The portion of the whorl next to the periphery above is generally convex, and the height is slightly greater proportionately to the width than in the normal forms. This makes the index somewhat higher than in the normal, but not higher than in the *extinct* forms. There are 5⅛ whorls normally, the same as in the form 2. An average size is: height 22 mm.; width 42 mm.; mean divergence 115°–120°; index .525.

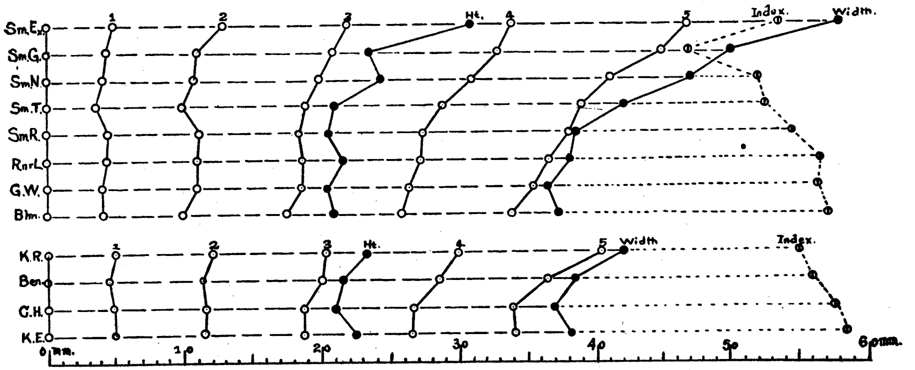

Fig. 6.—*P. a. goniasmos.* Comparison by whorls.

A most satisfactory comparison of these four types may be had by comparing their dimensions whorl by whorl, and such a comparison is given in the table below.

Comparison of the Average Dimensions from Selected Typical Specimens of the Four Types of P. a. goniasmos A. D. B. from Somerset Colony.

Type.	Whorl 1. mm.	Whl. 2. mm.	Whl. 3. mm.	Whl. 4. mm.	Whl. 5. mm.	Height. mm.	Width. mm.	Index.	Mean divergence.
Extinct	5	13	22	34	47	31	58	.535	115°
Gully	4.5	11	21	33	45	23.6	50	.47	130°
Normal	4.15	10.8	20	31	41	24.5	47	.52	125°
Hill-top	3.75	10	19	29	39	22	42	.525	118°

These may be plotted and will be found in fig. 6 along with the series from other colonies. The measurements of all the specimens from the Somerset colonies are plotted in fig. 5. Here the distribution of the hill-top, normal, gully and extinct forms is shown as regards frequency. The frequency curve for width shows distinctly the separation of these four types. Thus at width 42–43 mm. we have the limit of the hill-top forms and their blending into the normal forms; at 48 mm. the drop in the curve shows the passage from the normal to the gully forms, while between 52 and 53 mm. the extinct forms begin. Their (apparent) relative infrequency is simply due to the fact that comparatively few of the extinct shells were taken. In this diagram all measurements are to the nearest whole millimeter, the number of coincident measurements for any size of shell being indicated by the small numbers enclosed in the circles, whose centers indicate the dimensions.

Pleurodonte acuta goniasmos A. D. B. Plate X, figs. 1, 2.

At Somerset Road colony.

Shell varying from even flatter than the Somerset *normal* type to considerably more elevated; consisting of 5 whorls, the last whorl next to the periphery convex above and more so below, but with a distinct angle at the periphery; generally more elevated than in the Somerset forms and with an average index of .545, which is higher than even that of the Somerset *hill-top* shells. The index varies, however, from .473 to .612, being in general higher in the smaller shells, and only one of the larger specimens showing an index as high as .585; this was an old, weathered shell, perhaps representing an extinct form. The umbilicus is normally closed by an expansion of the lip, but in about 25 per cent. of the shells it was only partially closed. This is a one-toothed race like the Somerset shells—95 per cent. of the shells showed but a single tooth, and in only one was there a poorly developed second inner tooth. The diameter ranged from 35 to 44 mm. Average dimensions were: width 38.4 mm.; height 20.8 mm.; mean divergence 115° (110° to 120°); average index .545. Number of examples, 21.

This race, while smaller, closely resembles the forms from the Somerset colony. They are smaller than the smallest of these, however, the *hill-top* forms, and are somewhat higher in the spire also; the average index of the Somerset *hill-top* type is .525 as against .545 in this colony. In the young shells up to the second whorl the size is about the same as in the *normal* Somerset shells of the same developmental stage; from that point on the forms from this colony run smaller than any of the Somerset shells, compared whorl by whorl. Fig. 7 shows the measurements of the specimens from this colony, with their frequency curves of width and height.

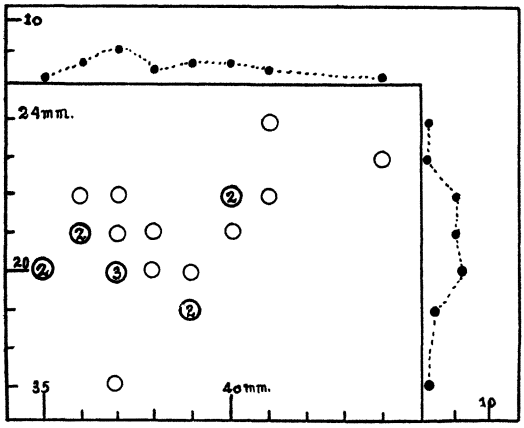

Fig. 7.—Somerset Road.

Pleurodonte acuta goniasmos A. D. B. Plate X, figs. 3, 4.

At the Ridge near Lincoln colony.

Shell varying from the form of the Somerset *normal* to much more elevated than those from Somerset Road and averaging higher than these in index; consisting of 5 whorls or often somewhat less (4⅞) and rarely of over 5⅛ whorls; with a slight concavity next to the periphery above on the last whorl in most cases, but this is sometimes wanting; convex below next to the periphery on the last whorl. The index ranges from .50 to .634, but the average from typical specimens is .565. The umbilicus is completely closed by the expanson of the lip in all of the 40 adult specimens examined. The forms are both one-toothed and two-toothed in about equal proportions; with two teeth there were 18 specimens, but of these 13 had the second inner tooth small; in all 45 per cent. were two-toothed. Of the remaining 22 specimens 20 had only one tooth, 50 per cent.; the other two had no trace of teeth, though the lip was heavy and well developed. Average width 38 mm.; height 21.5 mm.; mean divergence 112°. Number of examples, 40.

The average width is slightly less than that for the Somerset Road colony, the height, on the other hand, is slightly greater; this makes the average index higher, .565 for this colony as against .545 at Somerset

Road colony. The measurements of the specimens from this colony are given in fig. 8.

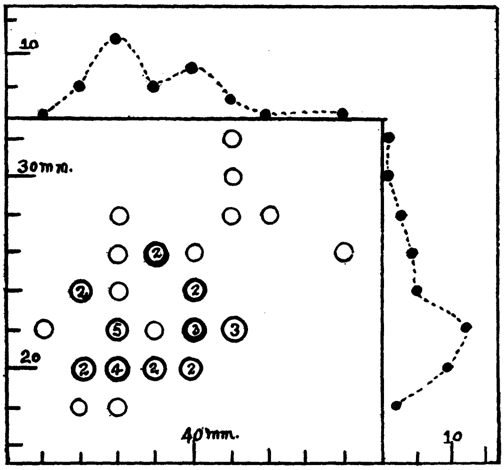

Fig. 8.—Ridge near Lincoln.

Pleurodonte acuta goniasmos A. D. B. Plate X, figs. 5–7.

At Garrett's woods colony.

Shell varying much in size and relative dimensions of height and width, but in general resembling the form of the higher shells from the Ridge near Lincoln colony; consisting of about 5 whorls, convex above and below the periphery on the last whorl; with a distinct angle along the periphery and, in some cases in the larger shells, with a slight concavity above the periphery in the last whorl. The index varies, the lowest being .48 and the highest .655, but a very large proportion of the specimens have an index of .55–.58 and the average for the typical specimens selected was .565. The plotting of the heights shows 22 specimens with a height of 19.5 mm., 20 with a height of 20 mm., 14 with a height of 20.5 mm., and 9 with a height of 21 mm.; the extremes of height range from 17 mm. to 27 mm. in the 83 examples measured, but these include 4 specimens which are semi-fossil, the largest of the series. The fresh shells run from 17 mm. to 23 mm. in height, these four semi-fossil ones from 24.5 mm. to 27 mm. The widths vary from 31.5 mm. to 40 mm. for the fresh shells and the four semi-fossil shells range from 40 mm. to 44 mm. The living forms show a sharp maximum in width at 36 mm., with 24 specimens (including those which measure 36.5); altogether 42 specimens range between 35 mm. and 37 mm. inclusive. The labrum shows a well-developed outer tooth in all but 5 specimens, which are toothless; of the toothed forms a less well-developed inner tooth appears in 38 specimens of the living form and 3 of the semi-fossil form, while 36 of the living form and one of the semi-fossil form have only the outer tooth. It will be seen, however, that the one-toothed and two-toothed forms are about evenly divided in this colony. The umbilicus is closed in all specimens by an expansion of the lip. Average dimensions are as follows: Width 20.4 mm.; height 36 mm.; mean divergence 109°; average index .565.

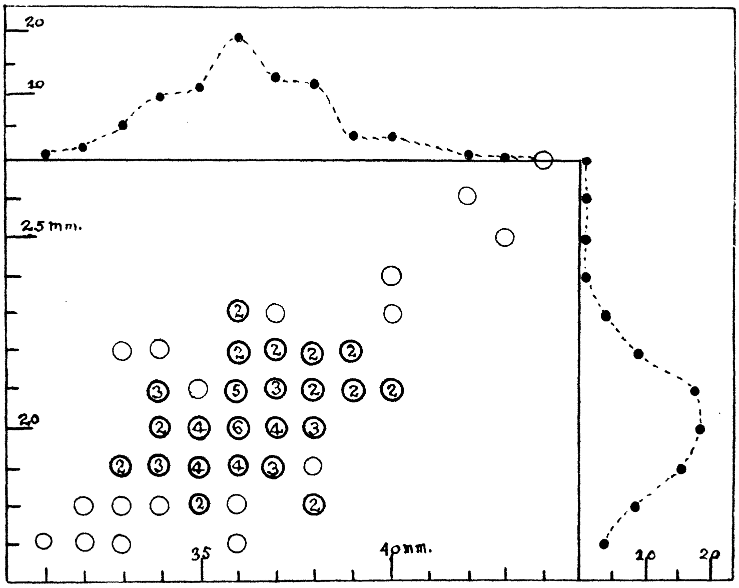

Fig. 9.—Garrett's Woods.

The form of the shell in this race is like that from the Ridge near Lincoln colony and somewhat higher in the spire than the shells from Somerset Road, but there are a great many small shells with very high spire. This is natural, for a large number of the specimens were taken from the hill-top, and, as at Somerset, so here, the hill-top forms run smaller than those found lower down on the slopes. The four semi-fossil forms are uniformly larger than the others, fig. 9, where the four highest shells are semi-fossil, and in these there is a slight concavity next to the periphery above in the last whorl. They probably represent the original race that reached this locality in the migration of the species, and that was subsequently modified to the present smaller form by being compelled to live under less favorable conditions, especially since the region has been under cultivation. They may have been driven to the shelter of this oasis in the cleared land by the cultivation, and even represent a form that lived under better conditions than those obtaining in the woods.

Pleurodonte acuta goniasmos A. D. B. Plate X, figs. 8–10.

At the Bloomfield colony.

A. *Old or Semi-fossil Shells*, 9 *examples.*—Shell with rather elevated spire consisting of 5 to 5¼ whorls and with, in most of the specimens, a concavity above, next to the periphery on the last whorl; in several of the specimens the shell is excavated or concave above the suture on the third and fourth whorls also, so that the very acute periphery persists up to the end of the fourth whorl where the excavation below the periphery disappears. The dimensions vary from 38 x 20.5 mm. to 43.5 x 25 mm.; the indices range from .515 to .612, but average .56. With the exception of two specimens, these old shells are uniformly larger than those now living in this colony. This is easily seen to be due to the fact that the woods at Bloomfield are disturbed and there is no possibility of migration from the lower ground as was doubtless the case when these semi-fossil shells were alive. Across the road from this woods the ground falls away into a long valley or pocket in the hills where the conditions of food and moisture must have been much more favorable when the country was uniformly forested than those obtaining in the colony at present. The forms are both one- and two-toothed, about equally divided, 4 have the outer tooth well developed and the inner one rather rudimentary, 5 have only the outer tooth. Average dimensions: width 40.5; height 22.7; index .56; mean divergence 110°.

B. *Living Race*, 25 *examples.*—Shell with rather elevated spire, consisting of 5 to 5¼ whorls; almost uniformly convex both above and below the periphery, which is not very sharp, in a few examples slightly excavated above next to the periphery. The dimensions range from 35 x 21 mm. to 39 x 23 mm.; the index varies from .53 to .625. They are about equally divided between two- and one-toothed forms; of the 25 specimens 12 have one tooth and 13 have two, but the inner tooth is only rudimentary in about one-third of these. The size varies, on the whole, considerably less than that for the old shells, but one is above 38.5 mm. in width, and that was 39 mm. Average dimensions: height 21 mm., width 37.3 mm., index 57 mm.; mean divergence 107°.

The dimensions of these two sets of specimens are given in the accompanying plot, fig. 10, in which all forms with a width of 39 mm. or over (with the exception of one, 39 x 23 mm.) belong to group A.

The shells in this colony were plentiful, and both in February and March and also in May living forms were collected in abundance. In March the young were perhaps somewhat more plentiful, but a good series were collected in May, when the suites above described were taken. The young ranged from 3 whorls to 4½ whorls in diameter, they move actively about above the surface of leaves and probably most of the migration occurs between a size of 2½ whorls and of 4 whorls. At about 4 whorls the adult characters begin to appear, and the umbilicus to contract as the size of the opening of the shell expands, but the development of the shell will be given in another place.

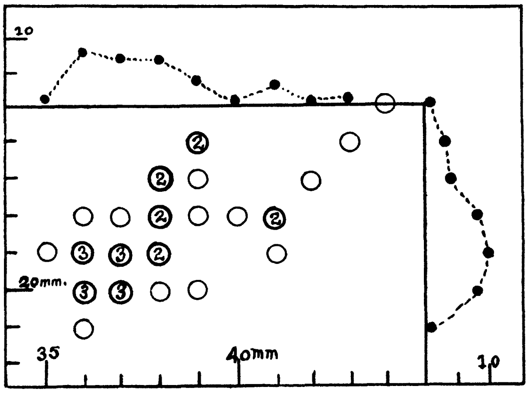

Fig. 10.—Bloomfield.

Pleurodonte acuta goniasmos A. D. B. Plate XI, figs. 1–3, 5.

At the Kendal Road colony, 3½ miles from Mandeville.

Shell varying from rather high in the spire to as flat as the Somerset *normal* forms, consisting of 5¼ to 5½ whorls; only 2 out of the 18 examples (Plate XI, figs. 3 and 5) had a depressed spire, so that the index fell below .50 (.455 and .487), but in 5 others it was below .53 (.51, .512, .512, .524, .525). On the other hand, 4 had a much elevated spire, above .60 (.607, .61, .62, .62). The average index for the whole series was .55. They include shells that range in index below the lowest from Benmore woods, and some are also nearly as high in index as the highest from this colony. The outline of the spire runs from nearly linear to somewhat convex, but all show a slight excavation above the periphery on the last whorl and the angle is rather pronounced, one or two have this angle at the periphery much rounded.

The two extremes of form are so different that they may well represent two successive migration waves, but the high-spire forms predominate. Two of the shells were probably semi-fossil (Plate XI, fig. 1), but their index is near the average for the group and they were not larger than many taken at this colony. In actual size the two flat shells above mentioned are probably as large as many *Somerset normal* forms, measuring, height 21 mm. by width 46 mm. and 23 x 42½ mm., respectively, with indices of .553 and .541. This colony was at a lower level above sea than any other examined in this region; it is, as noted above, the most northerly point of the *second* migration line which seems to be indicated in the specimens of this collection. The dimensions of the entire 18 specimens are given in the diagram, fig. 11, but, as will be seen, they are rather scattered. Average dimensions by whorls were measured for a small selected series of these specimens, they show that up to 2 whorls the diameter is equal or rather more than that of the *normal Somerset* forms, at whorl 3 about the same size and at whorls 4 and 5 somewhat smaller. When fully grown they are about the diameter of the Somerset *hill-top* forms. The index is higher than that of any of the Somerset forms, though near that of the Somerset Road forms. The average dimensions of the adult shell may be stated as, height 23.1 mm.; width 42 mm.; index .55; mean divergence in the flat forms 130°, in the forms with high spire 95°.

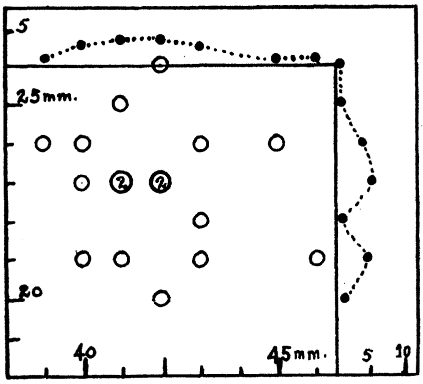

Fig. 11.—Kendal Road.

These forms are mostly one-toothed, 13 of the series had only the outer tooth and the other 5 had only a rudimentary inner tooth in addition. All have the umbilicus completely closed by an expansion of the lip.

The irregularity shown in the frequency curve of heights in fig. 9 is no doubt due to the fact that but a small series was taken at this station.

Pleurodonte aouta goniasmos A. D. B. Plate XI, figs. 4, 6, 7.

At the Benmore woods, Mandeville.

Shell ovate conical, rather higher than the last, consisting of $4\frac{3}{4}$ to $5\frac{1}{2}$ whorls, of which the last has a distinctly angled periphery, but is convex above and below and not excavated above the periphery, as is commonly the case in the Kendal Road colony. They do not include any very much depressed forms in the 42 specimens measured, these run above .53 in index, with the exception of 10 specimens whose indices range from .495 to .525; of the rest, 15 are above .575, and 8 of these are above 60. The average index for the entire series is .56. The heights vary considerably, but average about 21.5 mm., with an average width of 38.4 mm.; the mean divergence ranges from 120° to 110°. The highest index measured, .635, was in a shell of medium size, of which the dimensions were 23.5 x 37 mm.

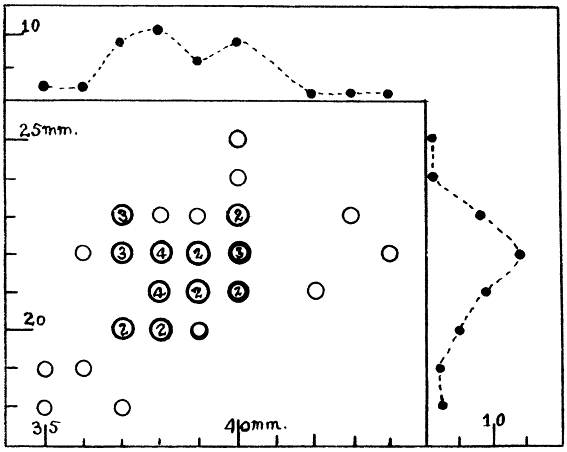

Fig. 12.—Benmore Woods.

The shells of this colony are prevailingly two-toothed, though the outer tooth is the only one that is strongly developed, and in the 25 that show two teeth ($59\frac{1}{2}$ per cent.) the inner tooth is rather small in most of the specimens. The other 17 specimens ($40\frac{1}{2}$ per cent.) only show one tooth, with no trace of the second, inner one. The umbilicus is normally closed, but is partly open in *one* specimen which is smaller than the average, although it does not seem to be abnormal or injured in any way. The only semi-fossil shell among the Benmore woods specimens has the highest spire of any measured, it gives 25 x 40½ mm.

The shells in this colony are smaller than those in the Kendal Road colony, and they are higher in the spire proportionately, or the index is slightly higher. There are none of the dimensions of the largest from Kendal Road colony, but one approaches it (22 x 44½ mm., as against 21 x 46 mm. from Kendal Road) and this has an index of .495, the only one with an index under .50.

Fig. 12 shows the distribution of size in this colony, the dimensions of the 42 specimens measured being given to the nearest whole millimeter. The frequency curve for widths shows that the majority range from 37 mm. to 40 mm., with a slight drop in the curve at 39 mm. The curve of heights shows a strong maximum at 22 mm.

Pleurodonte acuta goniasmos A. D. B. Plate XI, figs. 8, 9.

At Cedar Hill wood colony.

Shell generally rather elevated, consisting of 5 to 5½ whorls, in some cases slightly excavated above the periphery on the last whorl, especially in the higher forms otherwise convex at this point; with an index varying from .472 to .656, but in 69 per cent. of the specimens

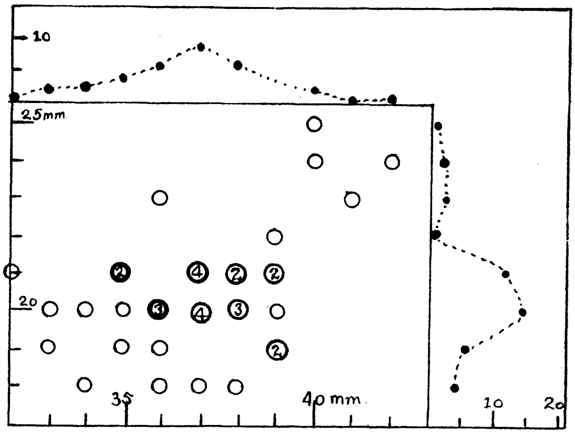

Fig. 13.—Cedar Hill.

it runs between .50 and .60 and is distributed as follows: under .50 in 4 specimens, .50–.55 in 13, .55–.60 in 16 and above .60 in 7 specimens. Three of these 7 specimens are very large semi-fossil shells, measuring 40 to 41½ mm. in diameter, the other 4 are small, very high shells of the fresh, living series, and range in size from 21 x 32 mm. to 225 x 36 mm. In the diagram of the measurements of this colony (fig. 13) the six semi-fossil shells are readily picked out, as they are seen to be the largest in the series. There are all gradations between the very high spired type and those which are moderately elevated only, but, as will be seen from the indices given above, only a very small number, less than 10 per cent., have an index near that of the *Somerset normal* forms or the flatter ones from Kendal Road colony.

Average dimensions are height 21 mm., width 37 mm., index .568; mean divergence varying from 90°–95° up to 105°–110°. The widths vary from 32 mm. to 43½ mm., but 29 of the shells (69 per cent.) have widths varying from 35 mm. to 39 mm. The heights also fluctuate widely, depending upon whether the shell has the more depressed or more elevated form.

The shells of this colony are both one-toothed and two-toothed forms, but the one-toothed form predominates and where two teeth are present they are of very unequal size, the outer one being well-developed and the inner one very rudimentary. More than 67 per cent. of the specimens have only the outer tooth developed, the rest have the outer quite large, but the inner one small. The number of examples studied was 42, and their dimensions are given, with their frequency curves, in fig. 13.

Pleurodonte acuta goniasmos A. D. B. Plate XI, figs. 10, 11.

At King Edward Hotel wood colony.

Shell more uniformly elevated than in any other colony, consisting of 5 to 5¼ whorls; the last whorl convex above and below, next to the periphery; very rarely is there a trace of excavation at this point. The whorls are somewhat convex above in those inside of the fifth whorl in some cases, in others the spire is more straight on the slope. The index runs uniformly higher than in the shells from the other colonies examined; in only one case out of 63 specimens does the index fall below .50 (to .487) and only 12 are below .55; that is, only 19 per cent. of the specimens examined. Of the rest, 31 specimens, or 49 per cent., are between .55 and .60; 19 specimens, or 30 per cent., have an index between .60 and .65, and one exceeds .65, being .658. In all, 81 per cent. show an index of .55 or above, and the average index for the colony is .585, much higher than any other examined. The shells of this colony do not vary in size quite so much as in some others; the extreme range of size is between 20 x 32 mm. and 23 x 42 mm.; most of them run between 21 x 35 mm. and 23 x 40 mm. The shells are prevailingly two-toothed, of the entire number examined in regard to this character, 68 in all, those with two teeth number 55 or 81 per cent. and the two teeth are both well-developed, although the inner tooth is somewhat smaller than the outer. The remaining 19 per cent. had only one tooth. Average dimensions are: height 22.4 mm.; width 38.2 mm.; index .585; mean divergence 98° to 102°.

This colony, the King Edward woods, is near the Benmore woods and the Cedar Hill woods, but is at present completely isolated from either as well as from other patches of woodland. From the proprietor of the King Edward Hotel I learn that it has been in its present condition for a generation, and is nearly untouched virgin woods. The constant character of a higher spire seems to have been fixed since the isolation of the colony, as the forms must have migrated in from the direction of Benmore woods or of Cedar Hill, judging from the topography.

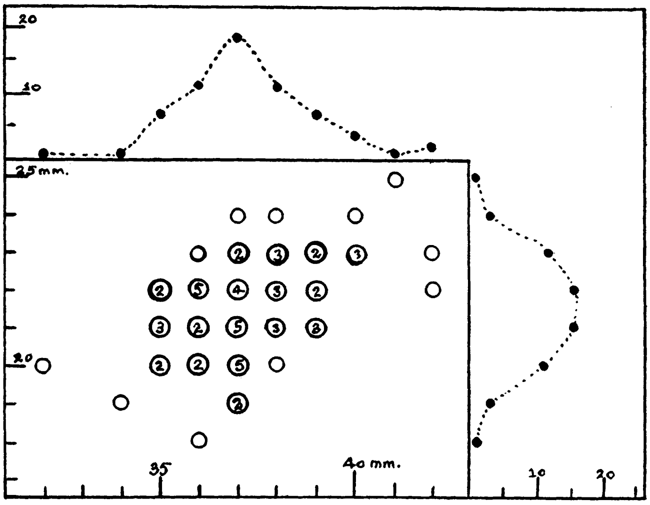

Fig. 14.—King Edward

Fig. 14 gives the individual dimensions of the shells of this colony and shows distinctly, in the regularity of the frequency curves of the two different dimensions, the unity of the colony and its undisturbed character. The curves here are progressive to the maxima and symmetrical, they do not indicate any admixture of foreign individual to disturb the integrity of the race, but they do appear to indicate an equilibration of the forms to the environment. The maximum of width is rather sharp, that of height is more gradually attained. As there seems to be in all of this stock a high and a low form intermingling, this isolated colony would seem to have nearly attained an equilibrium and fixed the characters of the new high-spired race. Topographically, this woods is lower in altitude than the Benmore or Bloomfield stations, but the old high-spired form shown on the Bloomfield diagram in the extinct shells is probably here found surviving in a more diminutive form. It is a hill-top race, for the King Edward woods is all hill-top, while the neighboring Benmore woods is cleared at the hill-top and the Cedar Hill woods includes hill-top and slopes and is much more wet than King Edward Hotel woods, so that stunting due to dry conditions is not so operative there. The species is still very plentiful here, another indication of adjustment of the forms to their environment. But, if such an adjustment as seems to be indicated has really taken place, it must have been accomplished since the isolation of this patch of woodland by the encroaching cultivation; that is, since the settlement and clearing of the adjoining lands, and probably within 20 or 30 years. That such change of conditions due to the influence of man in clearing the forest has resulted in smaller races in some species is easily demonstrated in the case of other Jamaican land mollusca, and some examples of it I intend to consider in a subsequent paper.

A comparison of the forms from these nine colonies, including the four types described from Somerset, whorl by whorl, as was done in the case of *Pleurodonte bainbridgei* from the five colonies compared under that species, shows a very definite gradation in the dimensions. For the purpose of this comparison a small number of specimens, five to ten, chosen as typical examples of each type or colony and representing the variation in size, were selected, making twelve groups of specimens, or some 75 specimens in all. Each one of these was then measured for its diameter at the end of the first, second, third, fourth and fifth whorl, also for its greatest diameter and height. The number of whorls and fractions of a whorl were noted. In measuring the diameters at the end of the first, second, etc., whorls all measurements started at the protoconch origin. In the larger snails the beginning of the suture is generally straight for half a millimeter or more and this straight part prolonged becomes a tangent to the curving suture line. From the beginning of the suture a line was drawn radially, and tangent to the first part of the suture; where this line crossed the suture was taken as the end of the whorls. The series of measurements thus obtained are strictly comparable, being all made on the same basis. With the heights and greatest widths they amounted to some 500 measurements in twelve series; and in nearly all cases represent 7 measurements for each shell. These were then taken in each series or type, whorl by whorl, and the corresponding measurements averaged, giving for each of the twelve types or series the average width at each whorl, the average greatest width and height. The same method was employed in measuring the dimensions of *P. bainbridgei* shown in fig. 4. Upon plotting and comparing these measurements (fig. 6), it was seen that when the colonies or types represented were arranged geographically they were at the same time sorted out into two series in which the gradation of size was continuous from one end to the other in each. These two series are (1) the four types from the Somerset colony, Somerset Road, Ridge near Lincoln, Garrett's woods, Bloomfield; and (2) Kendal Road, Benmore, Cedar Hill woods and King Edward Hotel woods. The first has eight members, from five colonies, the second represents four colonies. The first group (1) represents a line from Somerset and Ridge near Lincoln, approaching Mandeville from the northwest, and terminating at Bloomfield on the western outskirts of the town; the second group (2) reaches from Kendal Road on the northeast to the King Edward Hotel woods on the east of the town. They may very well represent two migration lines, as the forms probably migrated into this region from the north. The two ends near the town are separated by a high ridge and much cleared land, but the forms may have mingled in the past. These two groups of measurements are represented in fig. 6. The first at the top of the diagram is the Somerset-Bloomfield group, the lower is the Kendal Road-King Edward woods group.

THE SOMERSET-BLOOMFIELD GROUP.

The largest form of *P. a. goniasmos* found in the Mandeville district is the extinct race at Somerset, designated as Sm. Ex. in the diagram, with an average of 5¾ whorls and measuring 31 x 58 mm., with an index of .535. Then follows the gully forms (Sm. G.), the normal Somerset forms (Sm. N.), and the hill-top forms (Sm. T.). The successive whorls are marked 1, 2, 3, 4, 5; the height (Ht.) and the width are marked in black dots. It will be noticed that there is a gradual decrease in size in these four types in each whorl; even the first whorl showing this decrease, which indicates that the dwarfing begins in the egg. The irregular variation in height, and therefore in index, shown in the Somerset gully form (Sm. G.) is an expression of the observation that this form does not have the shape of the others and is probably another race, though closely related. The diminution in size for the whorls is accelerated after the third whorl and becomes very pronounced in the fifth whorl, but the width varies much more rapidly (as shown by the greatest width) than the height (Ht.). The index of the extinct form is, however, higher than that of the hill-top form, .535 as against .525. Comparing with these the other members of this series we see that the dimensions continue to decrease on the whole and the indices to increase, at least as far as Garrett's woods, which is really beyond Mandeville; though the Ridge near Lincoln forms (R. nr. L.) average somewhat higher than those of Garrett's woods (G. W.) and Bloomfield (Blm.), they are also higher than the wider form at Somerset Road colony (Sm. R.). The index of the Ridge near Lincoln form is then somewhat higher than that of the Garrett's woods form, but not higher than that of the Bloomfield form. There is hence a slight irregularity in the curve of heights and indices. The topography of the country renders it very probable that Garrett's woods and Bloomfield are in a migration line from the north, in which the Somerset and Somerset Road colonies would be the first stations represented on this diagram, or in this collection; the Ridge near Lincoln colony would probably be a station on another line from the Somerset region. That the forms migrated from the north, the high backbone of the island, after the last submergence of the island, is almost certain from the topography; therefore the forms whose measurements are given on this diagram, being arranged geographically, might represent the variation in a stock along a migration line.

THE KENDAL ROAD—KING EDWARD HOTEL WOODS GROUP.

A similar migration line is probably represented in the lower part of fig. 6, which gives the measurements for the Kendal Road (K. R.), Benmore woods (Ben.), Cedar Hill woods (C. H.) and King Edward Hotel woods (K. E.). In this series, again, variation begins with the third whorl, and becomes more pronounced in the succeeding whorls. The height and width decrease for the first three stations, but rise again at the fourth. This series was arranged geographically, but also to show a constant rise of index, as the Cedar Hill woods and King Edward Hotel woods are about equally distant from the Kendal Road Station. The rise in the index from the Kendal Road to King Edward woods is, as the diagram shows, from .55 to .585; although both width and height diminish from the one station to the other, the index rises, that is, the spire rises proportionately to the width. The index, therefore, gives a direct means of comparison of the relative heights of the spires; as it rises, the spire becomes higher. As has been stated above, this change in form is observed in passing from station to station in each of the series represented in fig. 6; that is, a geographical arrangement of the forms is also a morphological one.

VARIATION IN THE TWO GROUPS.

At Somerset, in passing from the base of the hills or from the valleys to the hill-tops, the form is observed to change, and the rise is quite noticeable as the tops of the hills are reached. From Somerset to the Ridge near Lincoln the rise in the spire is still continued, and this latter locality is a hill-top. At Garrett's woods and at Bloomfield the spires are higher than at any of the Somerset stations and as high or higher than at the Ridge near Lincoln. In the other series, from Kendal Road to the woods at King Edward Hotel, there is a similar rise in the spire. This change in the form cannot be correlated with change of altitude measured from sea level, but is directly connected with a diminution in size; as the size of the shell diminishes the shape changes, and the ratio of height to width increases, or the spire rises. Examined locally, as at Somerset, this change may be seen in passing from the base to the top of a hill, so that it may be stated that valley forms and those living at the base of the hill are lower in the spire than those living at the hill-top. The only place where valley and gully forms were seen in a natural, undisturbed condition was at Somerset. In passing from the gullies and shaded valleys, with their wealth of rank tropical vegetation and the ground covered with a thick moist layer of dead leaves, to the stony hill-top, with its hardwood trees and broom-palm, the number of specimens encountered became greatly reduced. On some hills at Somerset, scarcely a ground-living shell, such as *Pleurodonte,* was seen at the top of the hill, yet the shade of the woods was often very dense. But an examination of the ground showed that the surface coating of leaves was dry, it was mostly the fallen leaves of the broom-palm, which decay very slowly and do not form a good material for the growth of the fungus upon which the *Pleurodontes* appear to feed. The palm leaves form a sort of thatch on the ground and shed the water on the hill-top, hence the leaves are dry; and the loose stone on most of these hill-tops makes a porous layer, through which what water penetrates the palm thatch soon drains away. Comparing these Somerset hills with those examined elsewhere in the more cultivated regions, the comparatively small number of individual specimens encountered upon the hill-tops was very noticeable. But the molluscan population throughout all of this undisturbed region on the Somerset plantation was much less dense than in the majority of places that were examined in the more disturbed regions, and probably represents the original condition in these more cultivated parts. In such places as the localities in the cleared and cultivated region near Mandeville, as Garrett's woods, Bloomfield, Benmore woods, King Edward Hotel woods and Cedar Hill woods, many of the forms probably were driven to the hills by the advancing cultivations, and the molluscan population hence became more dense in these places. This would mean a mingling of the lower-ground forms with the hill-top forms, yet the general hill-top character is more pronounced here than in the hills at Somerset. The larger forms were absorbed by the hill-top races in these cases, and the clearing killed off the lower-ground forms that did not migrate, so that the smaller hill-top races were no longer strengthened by the constant mingling with the lower-ground forms and hence the reduced size became a fixed character. These isolated hill-tops, therefore, became isolated colonies, and strict equilibration of the forms within contracted environment, both as to the external influences and the mixture of substance due to hybridity, without mingling of the blood from the larger lower-ground forms, the supply of which was now cut off by their extinction due to advancing cultivation, could begin. The result is the development of the small hill-top forms now characteristic of these colonies near Mandeville, or what may be called the *Mandeville race* of *P. a. goniasmos.* They differ from the lower-ground forms, as has been shown, by being of smaller size and by having a proportionately higher spire; but, in the colonies near Mandeville, these characters are accentuated, as compared with the hill-top forms found in the Somerset region, where mingling with the larger, and in general flatter, forms is still possible.

THE MIGRATIONS.

Comparing all of the forms from all of the colonies, as is done in fig. 6, shows not only apparent migration lines, but indicates two waves of migration into the region from the north. The first was probably represented in the extinct Somerset race, and these as they moved south towards Mandeville became differentiated, as I have pointed out. The very old dead shells of the Mandeville region are generally rather high in the spire, higher than the living forms at Somerset of the same diameter. The Somerset gully forms I take to represent a second migration, they are the lower-spired form. At Somerset, the normal race has come from a mingling of these two stocks by long-continued hybridity, and the Somerset hill-top form with its reduced size is the result of this mingling. The same flat forms that resulted from this hybrid stock were seen at the Kendal Road and at the Somerset Road colonies; this hybrid, migrating into country occupied by the older, higher-spired forms, and mingling with them, produced the present Mandeville race. But this Mandeville race, as we see it now in the hill-top colonies that remain, is a development from this mingling of the older, high-spired form, and the later hybrid of this with the lower-spired gully form, this hybrid having come into the Mandeville district as a second migration wave. And the result of this mingling here to the south of Somerset has become, on account of its isolation in the hill-top colonies, a smaller, still higher-spired race than the ancestral one.

Causes of the Variation.

The rise of the spire from the bottom to the top of the hill or from the valley or gully to the top of the hill has been noted in other cases, but the cause assigned for the change of form has generally been the hypsometric change of pressure. Thus Arnauld Locard, in his *Etudes sur les variations malacologique du Bassin du Rhone,* published in 1881, says that the elongation of the spire is one of the effects of change of altitude upon molluscs. This had been noted previously by A. C. Recluz, in the case of *Helix pomatia* in the mountains of the Auvergne, and also in *Helix aspersa* in the region of the Midi. Locard made similar observations in the case of *H. pomatia* in passing from Lyons to Grenoble. Both observers noted a rise in the spire in passing from the lower to the higher altitude and both attribute this change in form to the diminution of air pressure in the higher altitude. In a paper published in 1904[3] Raffaelo Bellini reiterates this view that the elongation or rise of the spire is to be attributed to the influence of the diminished atmospheric pressure. Bellini's observations were on species observed on the island of Capri, and are embodied in a previous paper entitled, *Alcune osservazioni sulla distribuzione ipsometrica dei molluschi terrestri nell' isola di Capri,*[4] in which he notes the elongation of the spire in passing from the base to the tops of the hills, and attributes it to the diminution of the atmospheric pressure. That this is not the predominant cause in the case of the species considered in this paper the foregoing descriptions will make clear, for here we find at Somerset, some 2,250 feet in elevation, the lowest-spired forms of *P. a. goniasmos* encountered, while at the Somerset Road colony the spire is higher, but the altitude above sea level lower, less than 2,000 feet. At the Ridge near Lincoln the elevation is about 2,800 feet, but the form of *P. a. goniasmos* found here is lower in spire than that collected at the King Edward woods at an elevation of less than 2,000 feet, probably nearly one-third nearer the sea level than the Ridge near Lincoln colony. But the diminution in size in passing from the valleys and bases of the hills to the tops, which accompanies the rise of the spire, is an undoubted fact, although diminished atmospheric pressure is not here the controlling factor. That it should ever be a controlling factor does not seem likely, as the variation from day to day in barometric pressure at a given point may, in this latitude, at least, amount to what would be equivalent to a difference in elevation of 1,000 feet or even as much as 1,500 feet inside of 24 hours. The diminution in size and the rise in spire are independent of absolute altitude above sea level, but are noted in passing from the bottom to the top of one hill. There is in *P. a. goniasmos* a direct connection between these two characters, the size and the height of spire vary inversely. The cause of the diminution in size may well be the cause of the rise of the spire also. From the observations that I have made upon these Jamaica mollusks this diminution in size, which accompanies the rise in the height of the spire, appears to be controlled mainly by the distribution of moisture. Variations in the conditions of moisture may occur quite independently of the altitude, and I expect in a subsequent paper to discuss this influence in connection with some other species where altitude is not a factor, and where the distribution of moisture is not controlled by the altitude nor by the topography.

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[3] R. Bellini, L'influenza dei mezzi come causa di variazione e di disperzione nei molluschi, *Bolletino del Societa da naturalisti in Napoli,* XVIII, 1904, p. 159.

[4] *Rendiconto del II Cong. Zool. Italiano,* Naples, 1901.

On the hill-tops, as has been pointed out, the amount of moisture found in the ground, in the leaf cover in which these Pleurodonts live, is less than on the slopes of the hills, and, from the wooded valleys and gullies to the hill-tops, this moisture in the leaf cover steadily diminishes, so that, as has been shown, the available food for the molluscs diminishes from the lower ground to the hill-top. Quite as important is the fact that the hill-tops are only moist and the conditions of moisture favorable for the growth of the mollusks at intervals following rains. In the gullies and wooded valleys the supply of moisture and food is continuous, on the hill-tops it is intermittent. The forms living in the hollows and lower ground at any place are, therefore, continuously supplied with the necessaries of life, while those living on the hills are supplied intermittently. Growth is continuous in the lower-ground forms, but it proceeds with many stoppages on the hill-tops. In a given period of time, therefore, the lower-ground forms can grow on more days, perhaps often on twice as many days or even more, than those living in the higher slopes and hill-tops. In a given time the valley and gully forms can attain a much larger size than the hill-top forms.

There is one dry season in the island and, in general, in the West Indies, during the months from December until the "spring rains" begin, in April or May, and during this dry time the showers are rare. For the rest of the year they may occur at any time, with maximum rainfall in May and November in most years. During the dry season, all of the *Pleurodontes* are more or less inactive; when the rains begin in April, they at once begin to pair. The young born one summer have grown to the adult state and pair the next summer. Those which have had the greater number of days of activity or of growth—the gully and lower-ground forms—will hence reach a larger size than those which have had, say, half as many growing days during the wet season; all have been inactive during the dry season. In the two cases the growing days may stand as one to two, the inactive period of the dry season is common to both, and after the same lapse of time in each case the animal becomes adult. Naturally the form that could grow on the greater number of days and the form that had the most abundant food supply will attain the larger size. The diminution in size on the hill-tops can thus be connected with the conditions of moisture, the supply during the growing season being less in these situations.

The rise of the spire is effected by a closer coiling of the whorl or the suture line drops more rapidly as the spire rises, and the diameter of the coil, the cross section of the aperture, does not increase so rapidly as when the spire is flatter. In a subsequent paper on the growth of the shell I hope to treat this matter more at length. Any mechanical injury to the shell results in the dropping of the whorl below the periphery and a consequent rise of the spire. Lessened vitality, due to insufficient food supply or mal-nutrition of any kind, or in general what may be considered pathological conditions, seems to produce the same effect—a dropping of the coil and a consequent rise of the spire. Frequent stoppages of the growth of the animal due to periodic times of dryness would probably have the same tendency. On the hill-tops we find these conditions of periodic dryness and mal-nutrition during the season when the forms living in the lower ground are growing continuously under optimum conditions of moisture and food supply, and these conditions seem to me to be the controlling factors in the variation in size and form of shell observed, aside, of course, from the effects of isolation on hybridity.

Isolation under such conditions as obtain upon the hill-tops results eventually in an adaptation of the substance of the organism to its environment, however, and the equilibration produces a race that can live under such conditions, so that the number of individuals does not diminish in a given area, but rather increases with the diminution of size; by which a given food supply will serve for a larger number of smaller individuals.

Explanation of Plates VII–XI.

Plate VII.—*Pleurodonte* (*Eurycratera*) *jamaicensis* Gmel.
Figs. 1, 2.—The rather large forms from the Somerset colonies.
Figs. 3, 4.—A larger and smaller form from the Ridge near Lincoln colony; these are quite as large as the Somerset race.
Figs. 5, 6.—The small race from Garrett's woods colony.

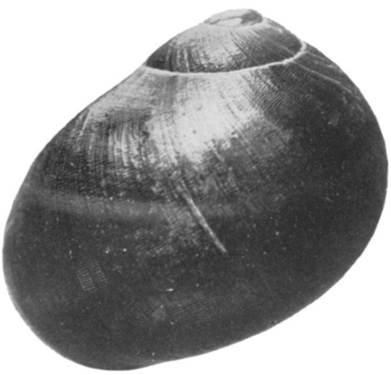
Plate VIII.—*Pleurodonte bainbridgei* Pfr.
Figs. 1, 2.—The form of the shell of this species at the Somerset colonies; it is the *P. bainbridgei pretiosa* of C. B. Adams.
Figs. 3, 4.—Two shells showing the form of the species at the Ridge near Lincoln colony, which somewhat approaches the *P. b. pretiosa* of Adams.
Figs. 5, 6.—Two shells from the Garrett's woods colony, showing the very slight depression of the suture line, much less so than at the Ridge near Lincoln.
Figs. 7, 8.—Two shells from the Benmore woods colony showing the depression of the suture at a minimum.
Figs. 9, 10.—Two shells from the Cedar Hill woods colony, showing their close resemblance to those from Benmore woods.

Plate IX.—*Pleurodonte acuta goniasmos* A. D. B. At Somerset.
Figs. 1, 2.—The extinct race at Somerset which shows the rather high spire of this type.
Figs. 3, 4.—The Somerset gully race, with its acute periphery and moderately elevated spire.
Figs. 5, 6.—The normal Somerset form found nearly everywhere except in the gullies and on the hill-tops.
Figs. 7, 8.—The Somerset hill-top form, a small race of the normal form.

Plate X.—*Pleurodonte acuta goniasmos* A. D. B. The Somerset Road to Bloomfield series.
Figs. 1, 2.—Forms from the Somerset Road colony, the present race is of the general type of the normal Somerset forms.
Figs. 3, 4.—The living forms from the Ridge near Lincoln colony.
Fig. 5.—The extinct race at Garrett's woods colony, showing the relatively high spire.
Figs. 6, 7.—Living forms from the Garrett's woods colony.
Fig. 8.—The extinct race at the Bloomfield colony, showing the rather high spire of this type.
Figs. 9, 10.—Living forms from the Bloomfield colony.

Plate XI.—*Pleurodonte acuta goniasmos* A. D. B. The Kendal Road to King Edward Hotel woods series.
Fig. 1.—The extinct race at the Kendal Road colony.
Fig. 2.—Living form of high-spire type at the Kendal Road colonies.
Figs. 3, 5.—Living forms of the flat type at the Kendal Road colonies.
Figs. 4, 6, 7.—Living forms from the Benmore woods colony. Fig. 4 is a two-toothed form and 6 is a one-toothed form.
Figs. 8, 9.—Living form from the Cedar Hill woods colony.
Fig. 10.—Living form from King Edward Hotel woods colony of average size; the highest-spired forms were found here. They closely resemble *Pleurodonte abnormis* Pfr.
Fig. 11.—Living form from same locality as 10, about the smallest specimen taken at this locality.

Note.—All figures in Plates VII–XI are natural size.



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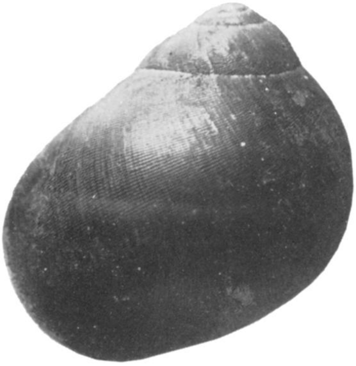

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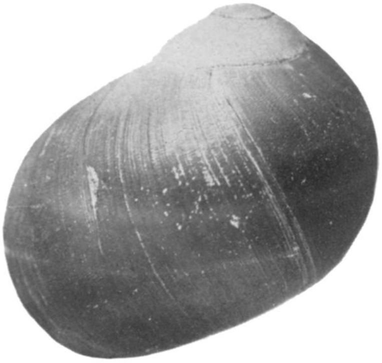

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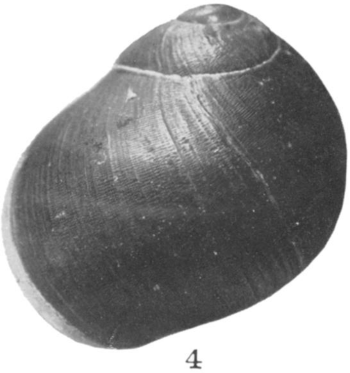

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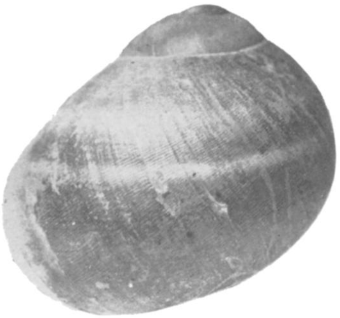

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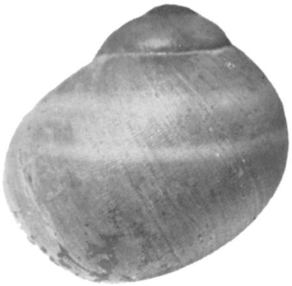

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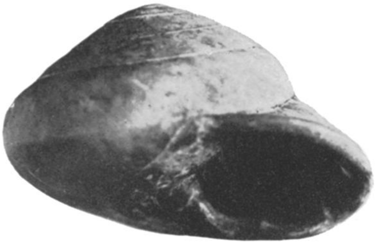
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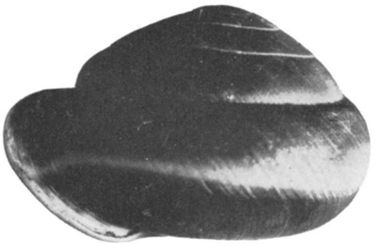
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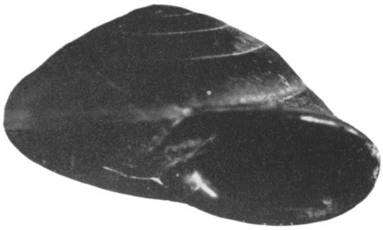
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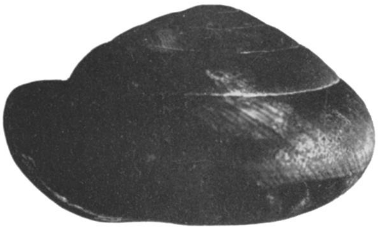
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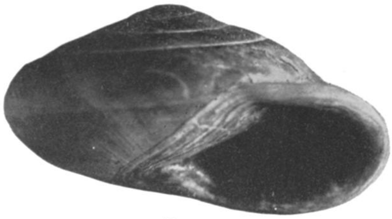
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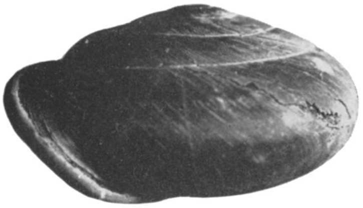
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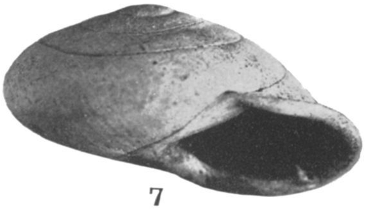
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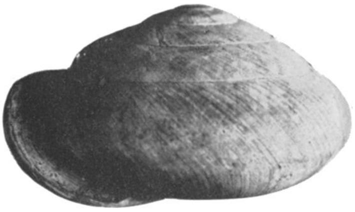
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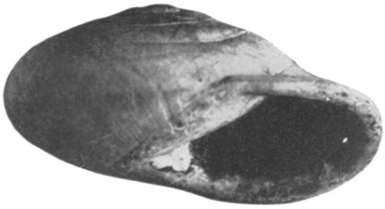
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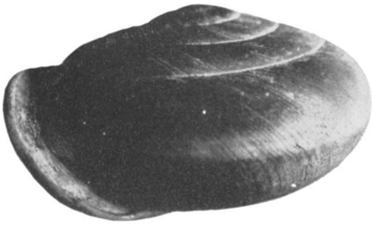
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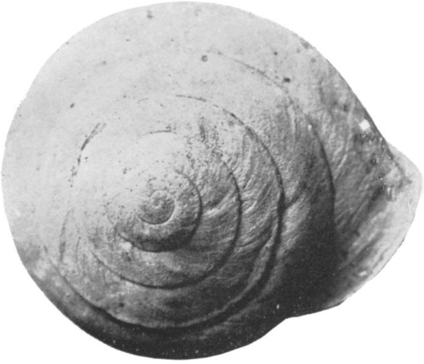

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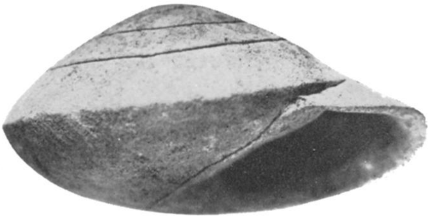

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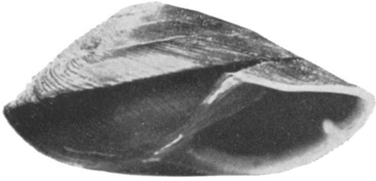

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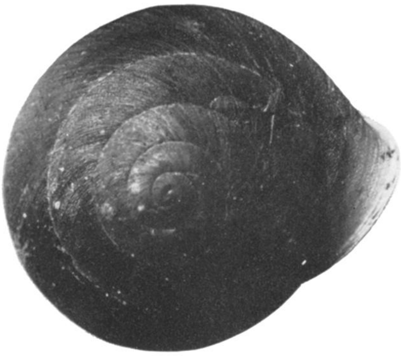

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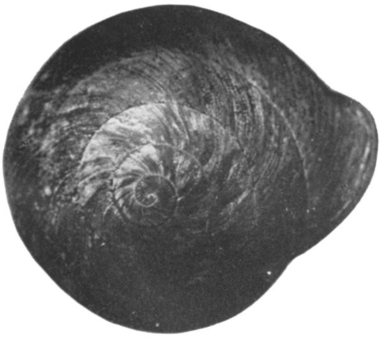

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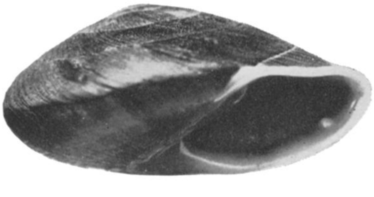

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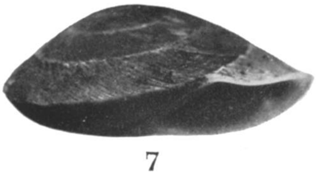

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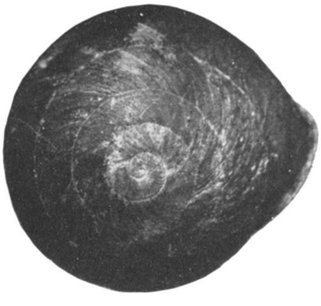

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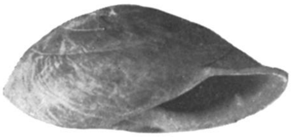
A. P. BROWN: JAMAICAN PLEURODONTS.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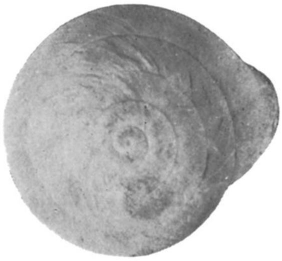
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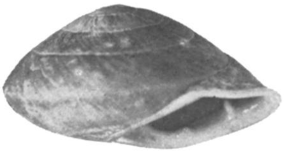
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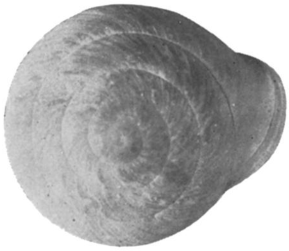
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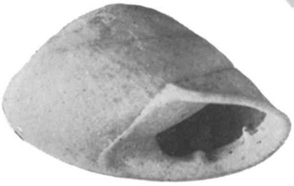
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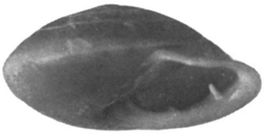
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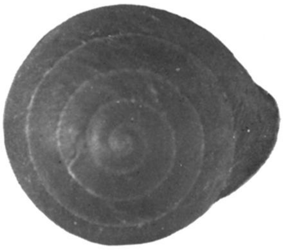
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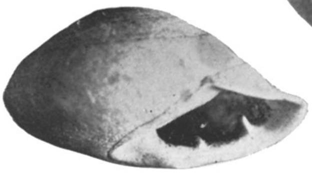
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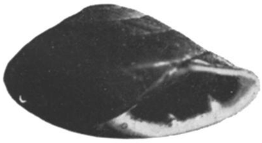
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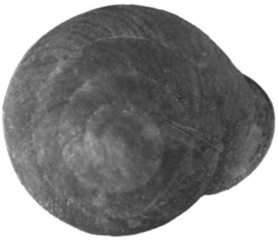
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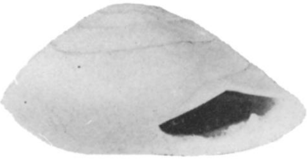
A. P. BROWN· JAMAICAN PLEURODONTS.



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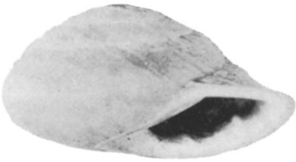

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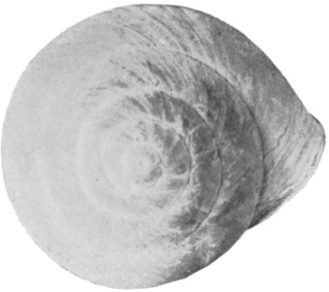

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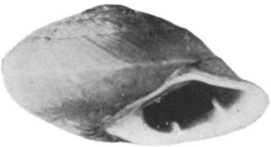

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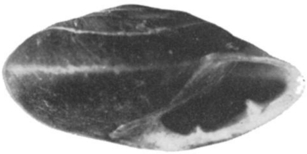

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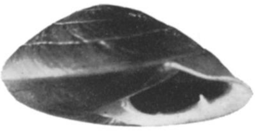

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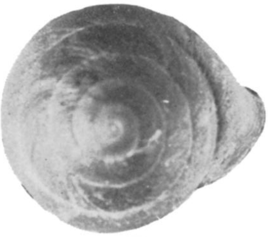

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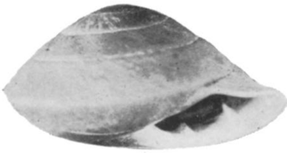

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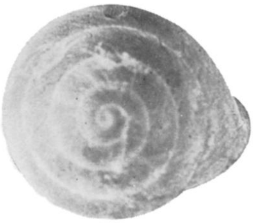

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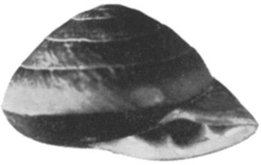

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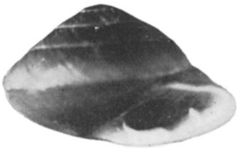

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A. P. BROWN: JAMAICAN PLEURODONTS.